Special Section: Summer Travel Guide

ASTRONOMY

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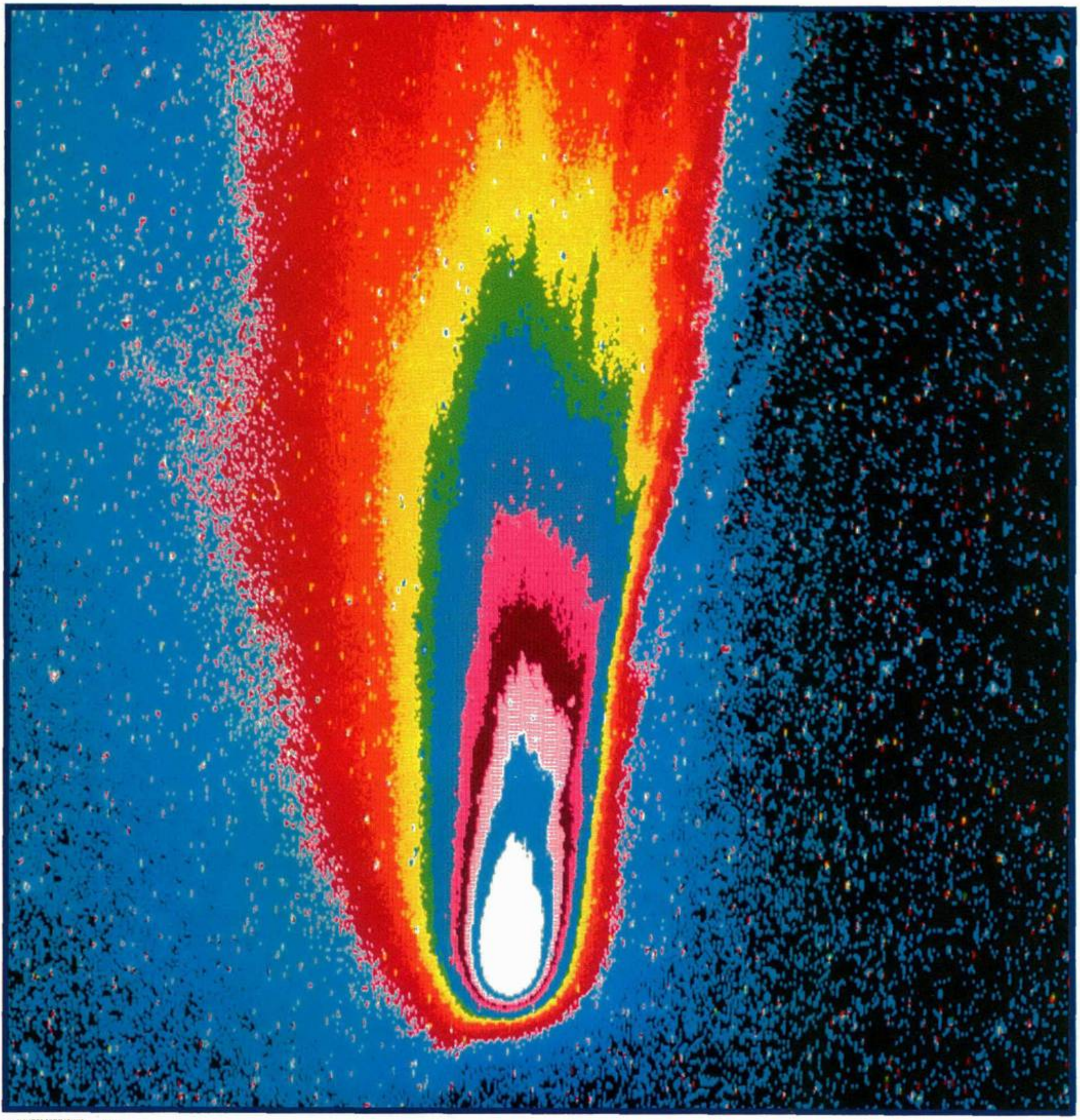
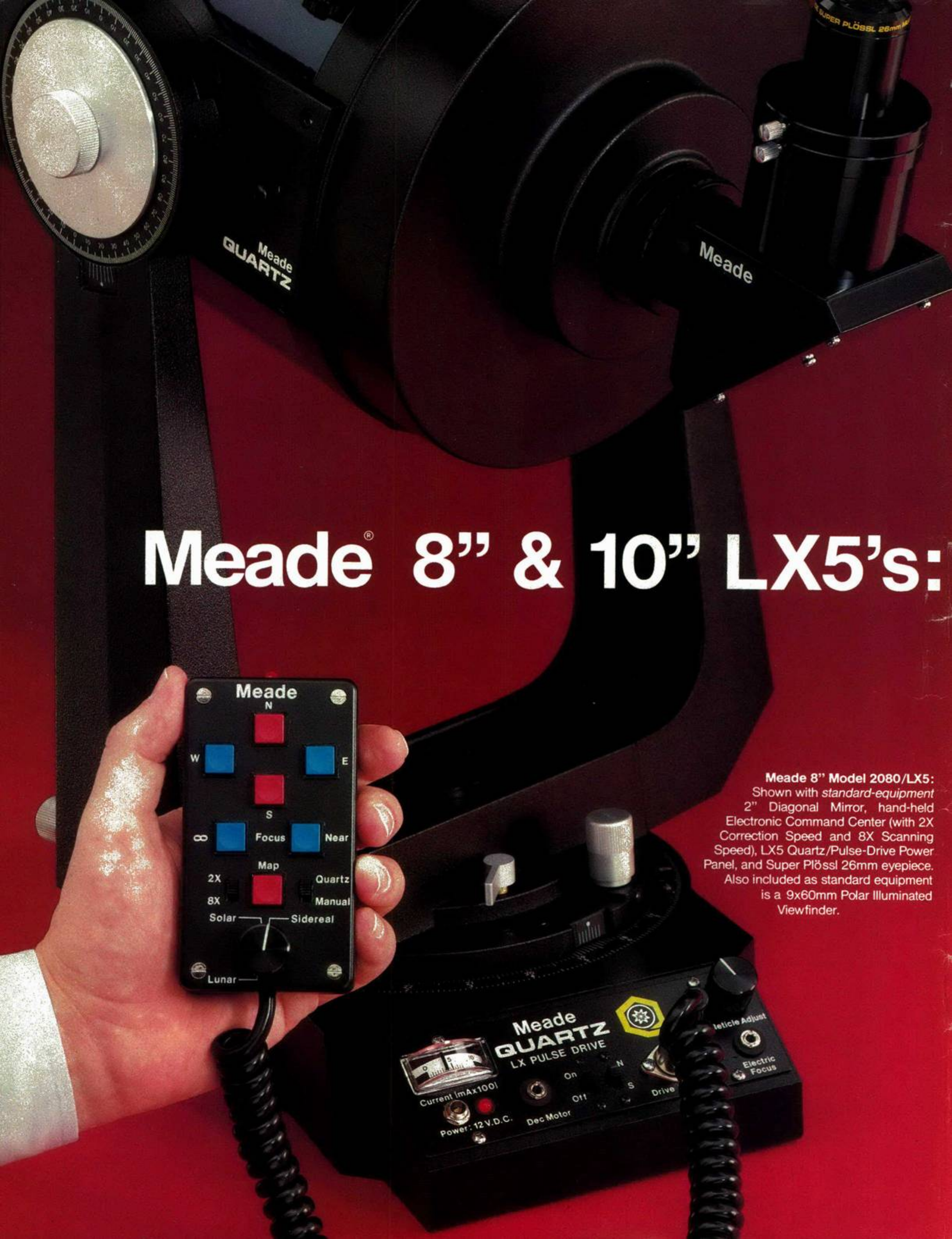
The First Days of Supernova 1987A

Comets: Key to the Primordial

Summer Celestial Calendar



Analyzing Comet Halley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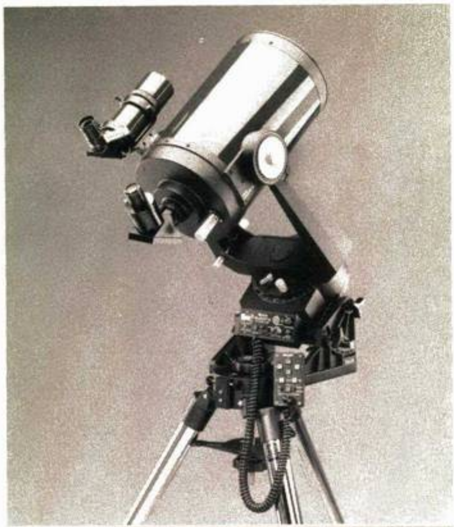

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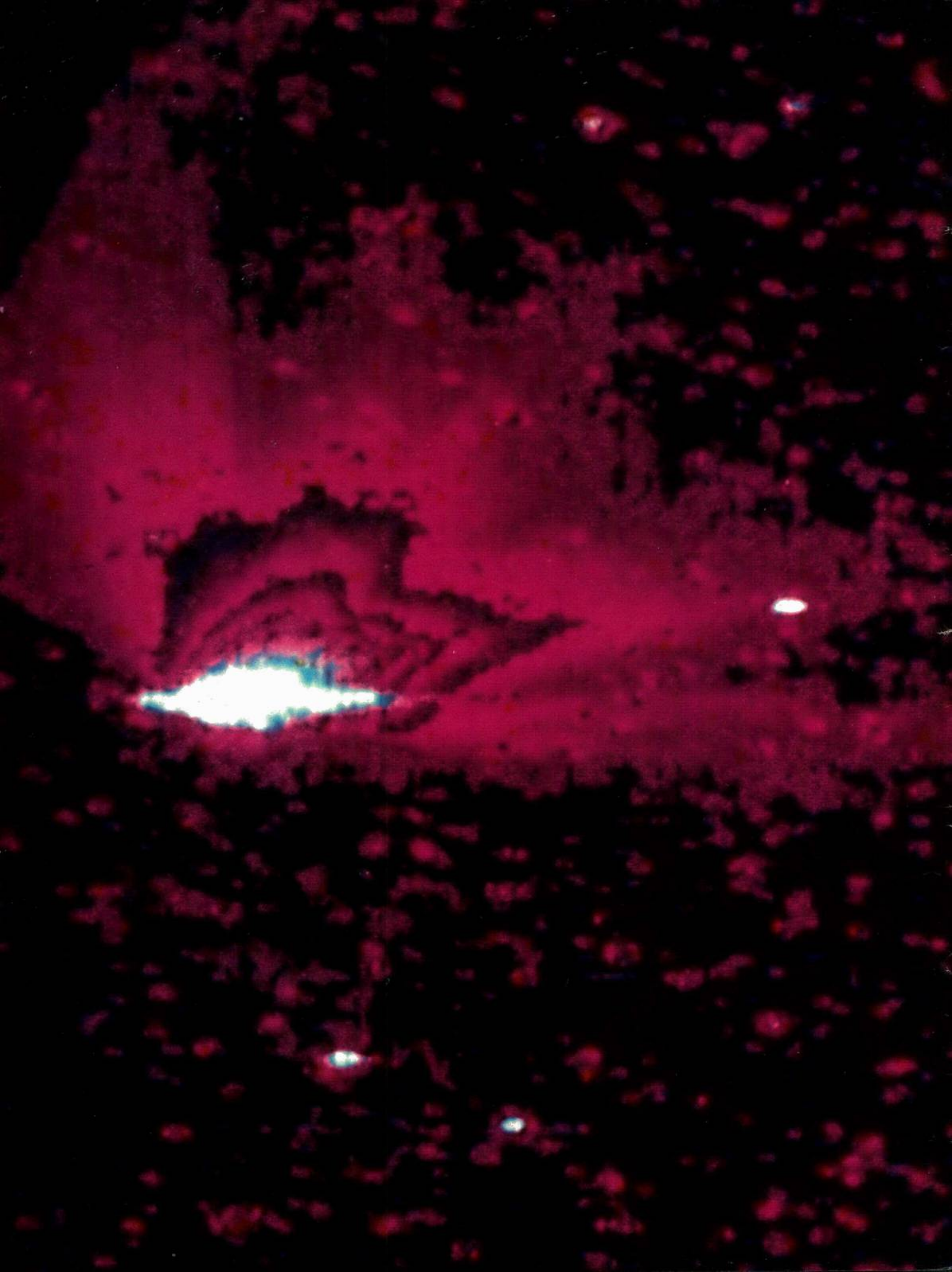

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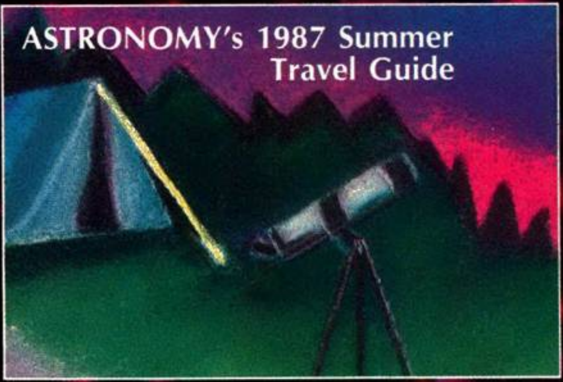

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Cover: Three weeks after perihelion passage astronomers using the UK Schmidt Telescope in Australia captured this image of Comet Halley on film and then digitized and displayed the result to search for structures in the comet's tail. Photo copyright © 1986 Royal Observatory, Edinburgh. These pages: On the morning of February 22, seven distinct tails fanned outward from the nucleus. Copyright © 1986 European Southern Observatory.

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ABC

SEARCH FOR THE PRIMITIVE

BY RICHARD BERRY

Comets are fluffy bodies made of recycled interstellar grains.

Three decades ago, before our first exploration of bodies beyond Earth, astronomers regarded the Moon as the key to understanding the solar system. There, it was hoped, we would find primordial matter — rocks left over from the formation of the solar system. The Apollo landings showed, however, that lunar rocks had been dried, melted, and reworked for a billion years before the Moon settled down and became a dead body. Nearly all traces of the origin of the rocks had been eradicated.

As the exploration of the solar system progressed, astronomers continued their search for the primitive — and reluctantly eliminated one body after another. Everywhere the robot eyes of spacecraft looked, they saw "processed" materials — eroded and battered rocks, shattered asteroid-size satellites, and melted icy moons.

What had become of the original material everything

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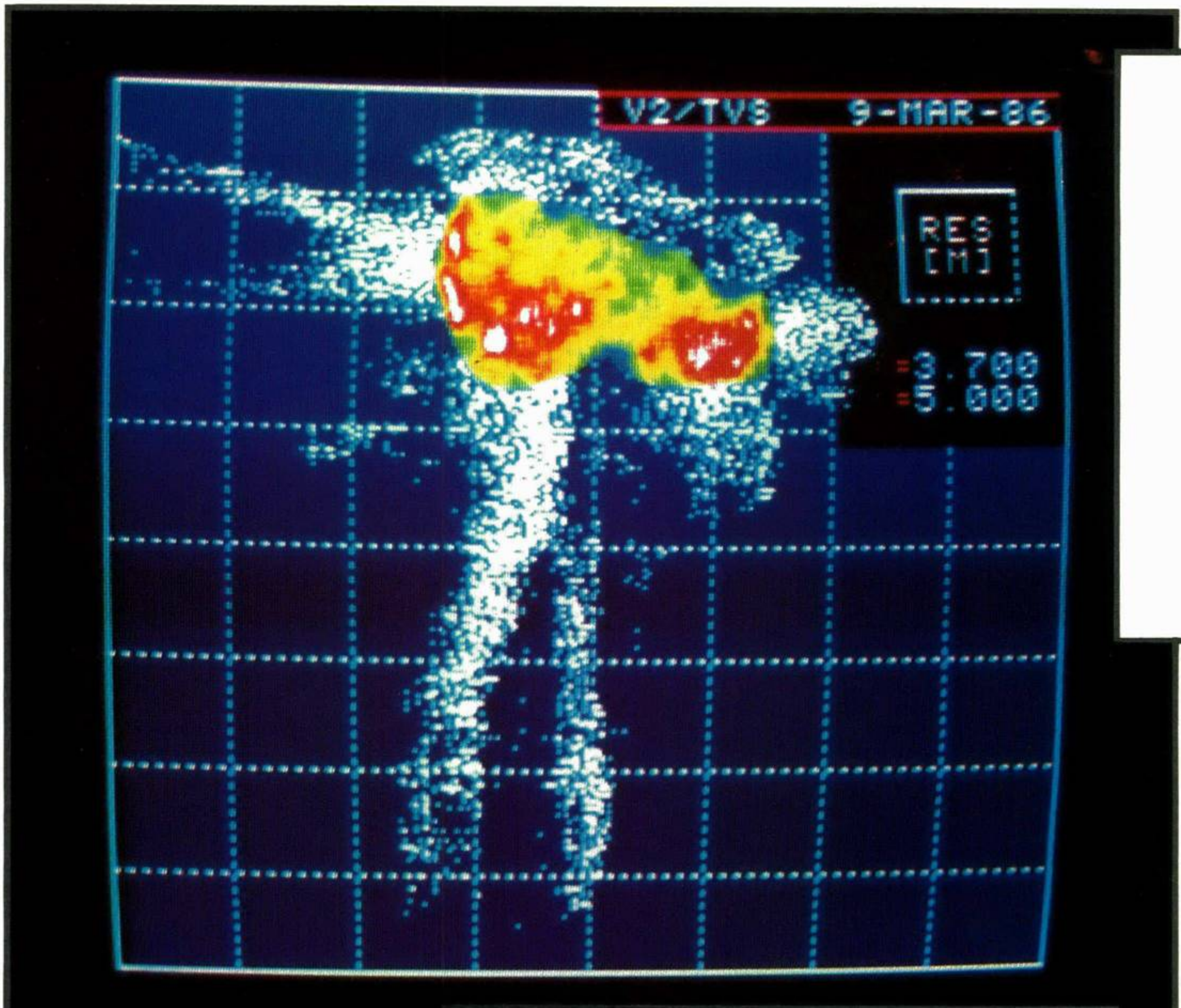
Left: **The European Space Agency's Giotto spacecraft recorded the nucleus of Comet Halley in exquisite detail. The bright dust jets, the lumpy terrain, the coal-black surface, and most of the pristine interior of the 15-kilometer-long black snowball hold clues to the origin of our solar system.** Above: **Seen from Earth on April 14, Halley displayed a broad dust fan and narrow gas tail. (Full photo credits on page 22.)**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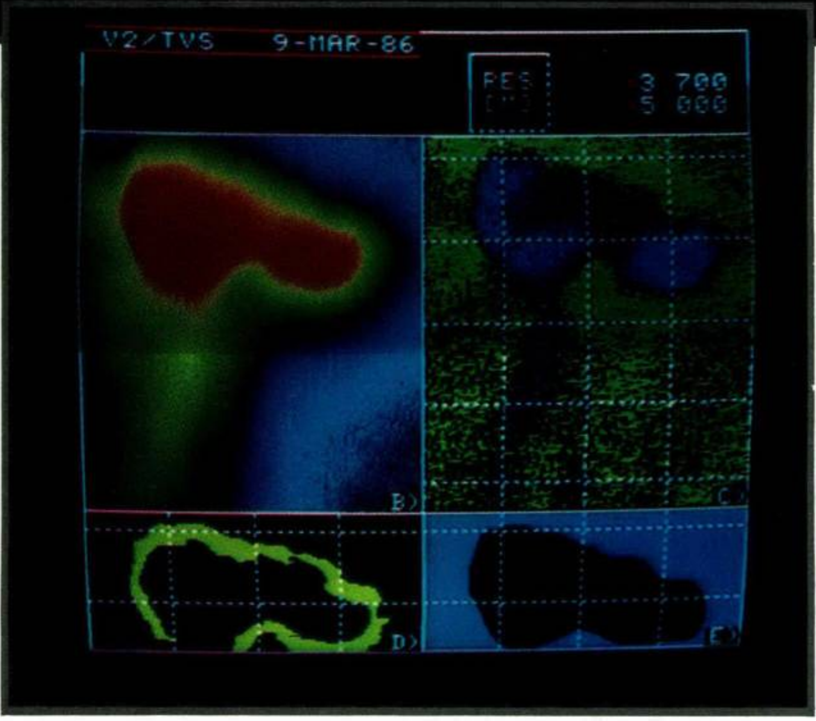
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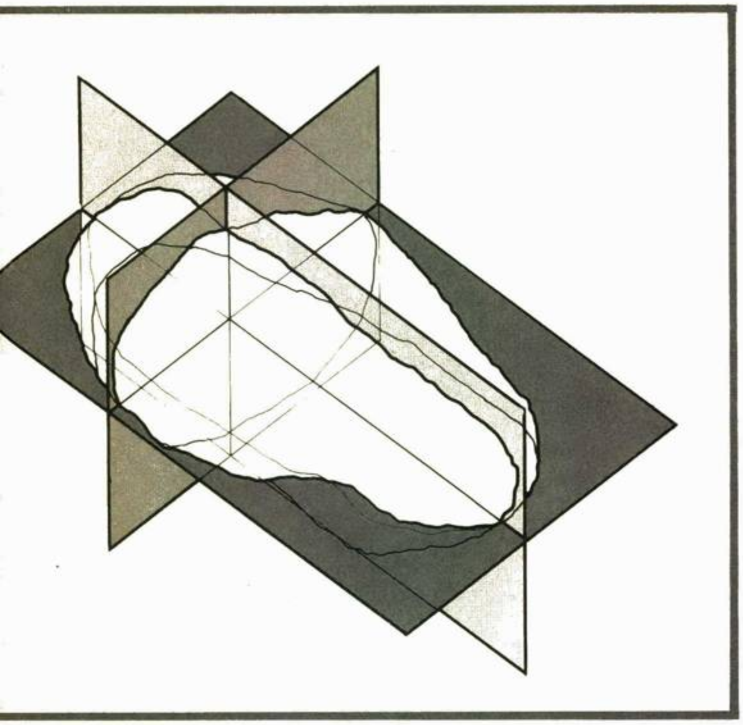


Soviet scientists extracted the three-dimensional shape of Comet Halley's nucleus from a suite of seventy of their best spacecraft images. Top left: **A composite image showing the profile of the nucleus in red, green, and yellow, and the jets in white.** Lower left: **The brightness "solid" of the best Vega 2 image. The edge of the nucleus occurs where the slopes of the brightness "mountain" are steepest.** Lower right: **Successive stages in extracting a profile of the nucleus from a single television image.** Above: **The nucleus as observed by Vega is 16 kilometers long, 8.2 wide, and 7.5 high. Computer images courtesy G. A. Avenesov.**

was made of? Had the consolidation of the primordial material into planets blasted all signs of its origin into oblivion? Had the intervening 4.6 billion years eradicated every trace of the raw materials from which the solar system was made? Was none preserved in some quiet backwater, in some deep freeze, for humans to study?

Of all the bodies in the solar system comets now stand out as the best place to look for these raw materials. Ever since the early 1950s, when Fred Whipple's "dirty snowball" model tabbed comet nuclei as frozen balls of ice and meteoric dust and Jan Oort made sense of cometary orbits by postulating an immense reservoir of comets some 50,000 astronomical units (AU) from the Sun, astronomers have recognized that comets might be made from the primordial stuff of the solar system, remnants of the solar nebula.

There were doubts of course. Comets might have been interstellar tramps, leftovers from the formation of other stars or solar systems, wandering the interstellar spaces until the Sun captured them. Or, comet material might have turned out to be as altered as the rocks in the lunar crust: shocked, crushed, melted, and refrozen.

Yet that has not turned out to be the case. The fleet of spacecraft that swung past Comet Halley in March 1986 established that Comet Halley and, in all likelihood, most comets are composed of the raw stuff of the solar system, have been preserved cryogenically in deep space, and are the primitive building blocks of the planets.

In the Beginning

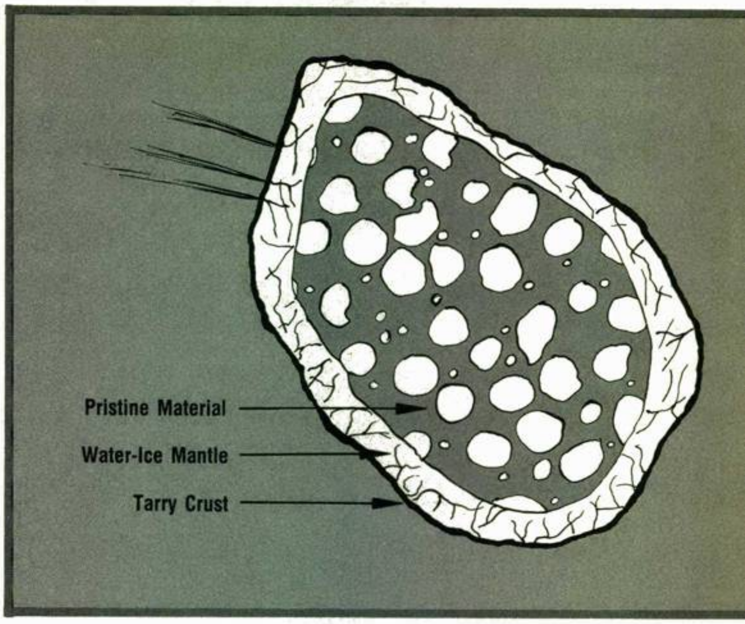
The solar system formed from the leftovers of an earlier generation of stars. When our Galaxy formed some 10 billion to 12 billion years ago, the universe was made almost entirely of hydrogen and helium. Stars formed and through nuclear fusion created heavy elements (carbon, oxygen, silicon, sulfur) in their cores. Massive stars are short-lived; when they die, they explode as supernovae, blasting the heavy elements into space where they spread as a gas through the spiral arms of the galaxy. Eventually some of the "enriched" interstellar gas, compressed by the gravitational field of the Galaxy's spiral arms, collects into cold, dense clouds.

Deep in these clouds strange things happen. Protected from starlight, the atoms collide and combine to become molecules of water, carbon monoxide, linear hydrocarbons, alcohol, and formaldehyde. Tiny particles of graphite, an ubiquitous form of carbon that sometimes forms in the atmospheres of cool stars, can serve as centers of condensation. In the extremely cold environment inside the cloud, molecules that hit these grains stick to them, and the grains grow thin coatings of ice. Inevitably, over millions of years, gravity draws gas and tiny grains together until all the material in an enormous volume of space falls together, flattens into a vast nebula, and a star forms in the center.

Astronomers observe these processes today in giant molecular clouds. Although these clouds are optically dark, at microwave radio wavelengths the molecules in them shine brightly. We know their characteristic temperature (a few tens of degrees above absolute zero) and their densities (several billion atoms per cubic meter). We see stars forming in them too, and not just luminous, short-lived stars that form in a region like the Orion Nebula but low-mass stars like our own Sun, stars that form without a great deal of fuss and fury, stars that may well have planets.

The shape of the nucleus has been described in terms of vegetables like potatoes, peanuts, and avocados. Vega believes it is an avocado, and Giotto thinks of it as a peanut. You can take your pick.

Although a star converts everything that falls into it to incandescent gas, solid bodies form in the cold nebula. First grains, then clusters of grains, then clumps, then plan-



Never has a comet been so thoroughly investigated. Above: **A cutaway view of the structure of Comet Halley.** Top right: **From Vega images Soviet scientists reconstructed this contour image of the three-dimensional shape of the inner coma.** Lower left: **A color-coded 3-D image of the nucleus.** Lower right: **Using the same techniques doctors use in CAT scans, Vega researchers constructed a cutaway through the nucleus and jets. The nucleus is at the center. Computer images courtesy G. A. Avenesov.**

etesimals, then planets form. Close to the warmth of the star, volatiles evaporate, leaving refractory materials behind to form dense, rocky planets. Farther out, gas and grains build the massive giant planets like Jupiter and Saturn. Near the outer edges of the nebula, where grains keep their coatings of ice, planets like Uranus and Neptune form from billions of icy planetesimals.

Building a planet changes the material the planet is made from. The rocky planets melted, and volcanic lava spilled across the cratered plains. Jupiter and Saturn homogenized everything that fell into them, and Uranus and Neptune turned billions of tiny, icy planetesimals into huge, gassy bodies. Even Pluto, with a density considerably greater than that of solid ice, seems to have processed raw nebular material into a ball of ice with a rocky core.

Yet something remains. Somehow some of the planetesimals escaped being incorporated into planets. Although the processes that put them there are still not clear, many hundreds of billions of comets orbit the Sun some 50,000 AU out. Happenstance brings them to us: the gravitational fields in the Galaxy or of passing stars deflect them inward. Comet Halley is one such body, captured in its present orbit perhaps a thousand orbits ago by one of the outer planets. Comet Halley is thus a sample of the primitive material of the solar system that conveniently visits us every seventy-six years.

Gathering Data

The observations that led astronomers to recognize Comet Halley as a primordial cosmic snowball are every bit as amazing as the conclusion itself. Support comes from measurements of the comet's orbit dating back hundreds of years, as well as from the most recent *in situ* sampling of cometary materials by the Giotto and Vega spacecraft.

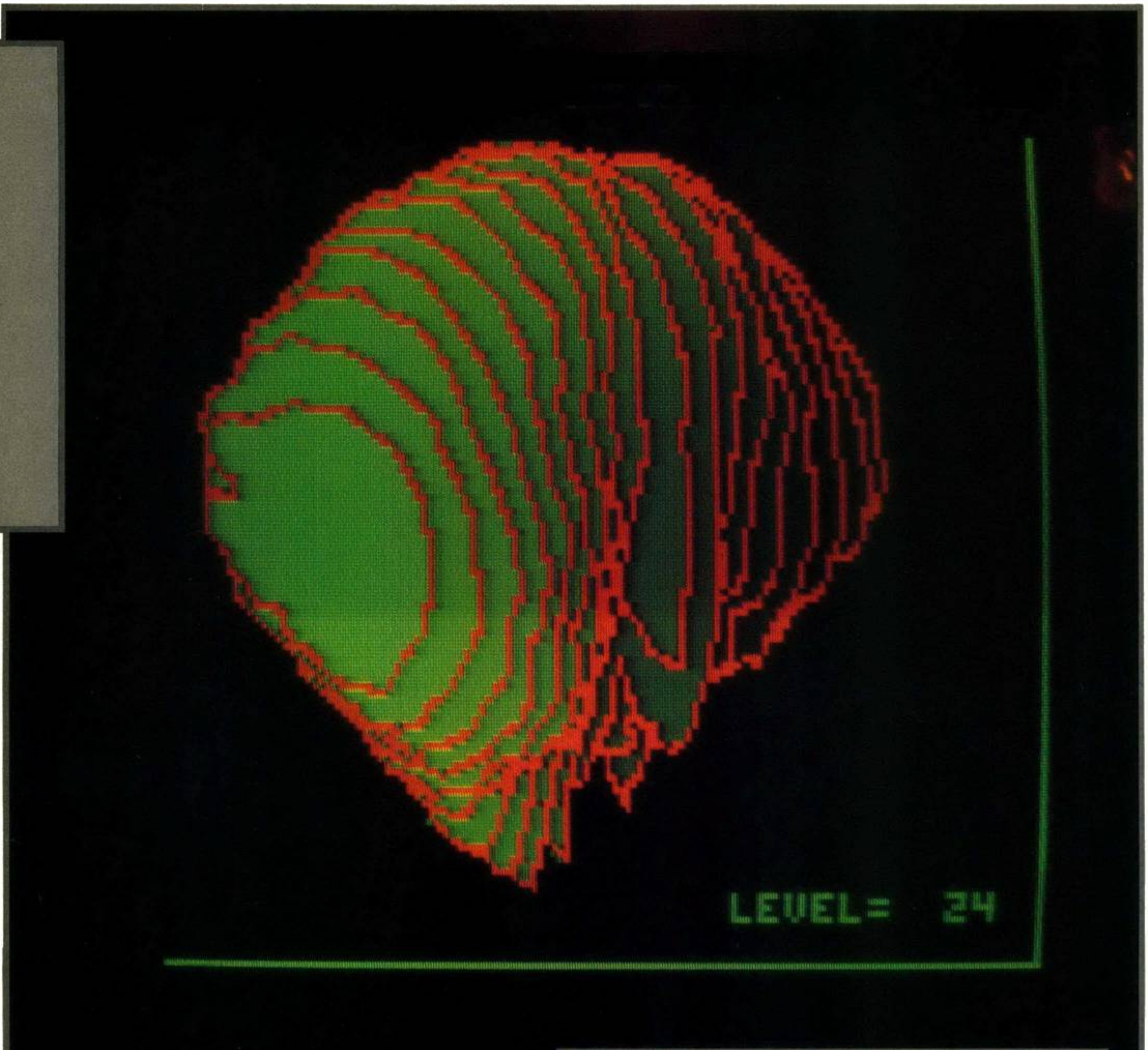
The picture of a comet as an icy conglomerate — a mixture of ice and meteoric dust — has certainly been supported by the present mission.

Before astronomers can make any claim to understanding a celestial body, they must know certain fundamental facts about it. First, how big is it? Before the flybys, astronomers thought that the nucleus of Comet Halley would turn out to be about 6 kilometers in diameter. They based this prediction on the estimated brightness of the nucleus and some assumptions about the grayness of a "dirty ice" body. When Giotto and both Vega spacecraft photographed the nucleus, however, they revealed a black object shaped like a huge avocado, slightly fatter at one end than at the other, some 16 kilometers in length, 7.5 kilometers in width, and 8 kilometers in breadth. This works out to a total volume of between 400 and 500 cubic kilometers.

This measurement was considerably more difficult to make than it might seem. The jet black nucleus was sheathed in a bright cloud of dust, which made it difficult to determine where the nucleus ended and dust began. Soviet scientists resorted to sophisticated edge-detection analyses to derive the silhouette of the nucleus. Because Vega viewed the nucleus from a variety of angles as the spacecraft flew by, the imaging team has been able to reconstruct the nucleus in three dimensions and thus derive the estimate of its volume.

Giotto passed much closer to the nucleus and took much sharper pictures, but it saw the nucleus backlit and from a small range of angles. The camera was designed to swivel and track the nucleus as Giotto flew past. Unfortunately, data transmission from the camera stopped just before closest encounter, when an impacting dust grain from the comet set the spacecraft spinning slightly askew. Only by combining the sharp Giotto pictures with the wide angular coverage of the Vega pictures was it possible to obtain a satisfactory measure of the total bulk of the nucleus.

It is equally important to know the mass of a celestial body, but there is no direct way to "weigh" a body like a comet nucleus. Luckily, though, Halley is an active comet. Because the gas and dust jets that spray from Halley's nucleus act like little rockets, they alter the orbit of the comet. From estimates of the amount of material being



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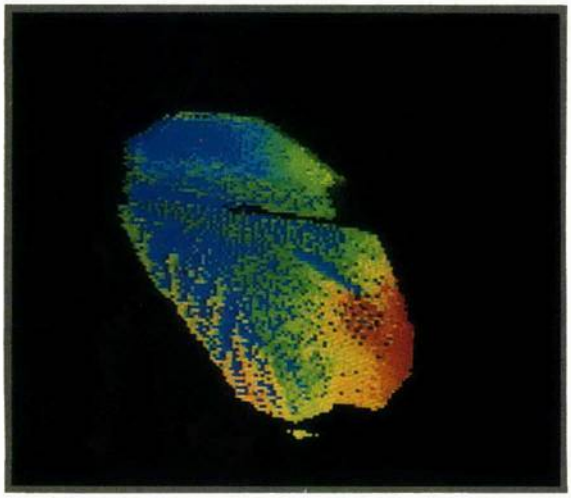
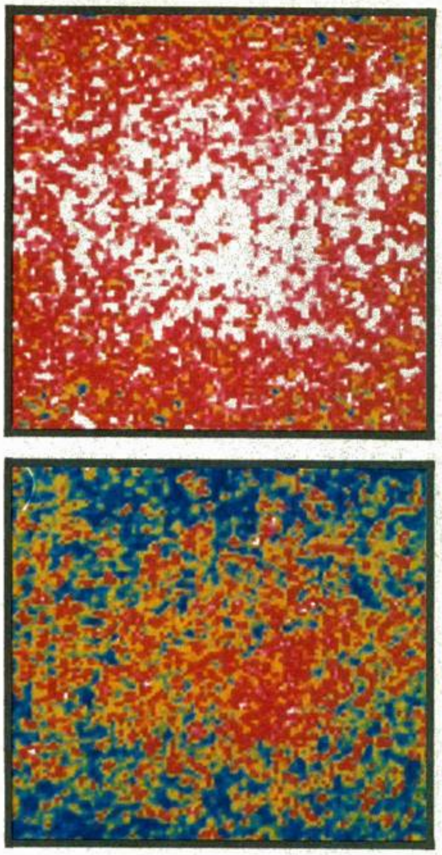
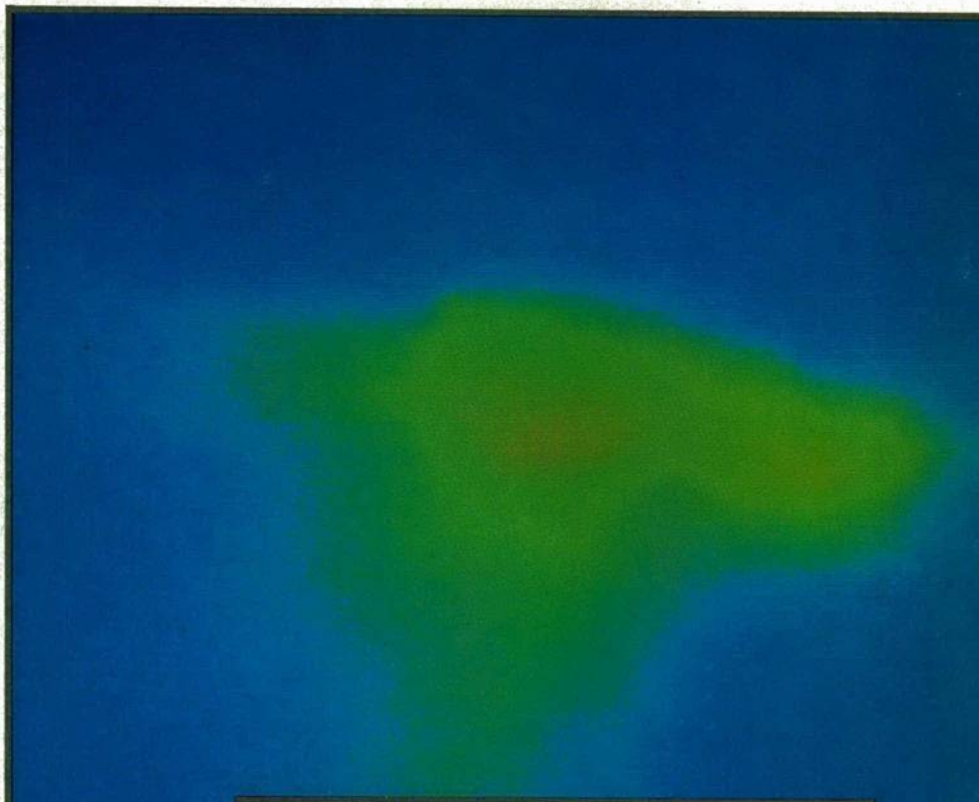
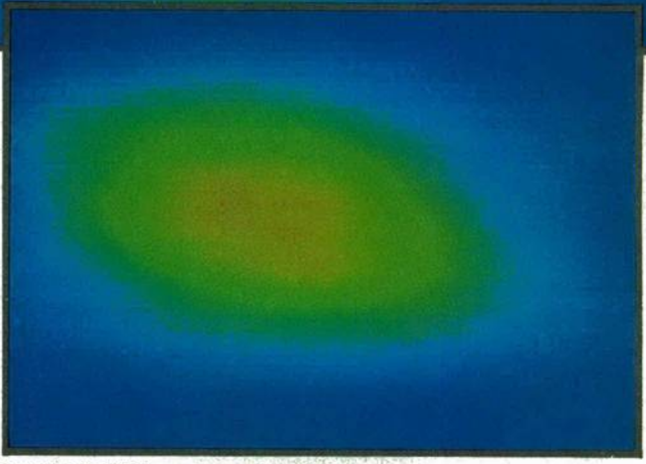




Above: **Enveloping Comet Halley was a huge cloud, or corona, of glowing hydrogen gas. These images, taken a day apart in the ultraviolet Lyman-α line by the Japanese Suisei spacecraft, show the comet "breathing" — its brightness rising and falling with a 2.2-day period.**





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Above, top: **As Vega 2 approached Comet Halley on March 9, its cameras recorded the cometary nucleus. From a range of 8,000 kilometers the images show the profile of the nucleus and a number of dust jets.** Above: **On March 6, from 9,000 kilometers, Vega 1 recorded a thick cloud of dust enveloping the nucleus. According to Soviet researchers, the nucleus appears nearly head-on in this frame.** Top right: **An early version of the Giotto camera's frame #3416, showing the nucleus as color-coded brightness contours.** Lower right: **Three frames in the Giotto camera approach sequence. The frame at left is #3416. The Giotto image on pages 6 and 7 is a composite of the best frames from this sequence. The three frames were taken from ranges of 25,700, 9,500, and 5,000 kilometers respectively. The resolution of the last frame is 200 meters.**

ejected in the jets and some judicious assumptions about the orientation of the jets, it is possible to calculate the force the jets should exert on the nucleus. Experts in orbital mechanics have tentatively agreed that a mass between 50 billion and 130 billion metric tons satisfies the observations.

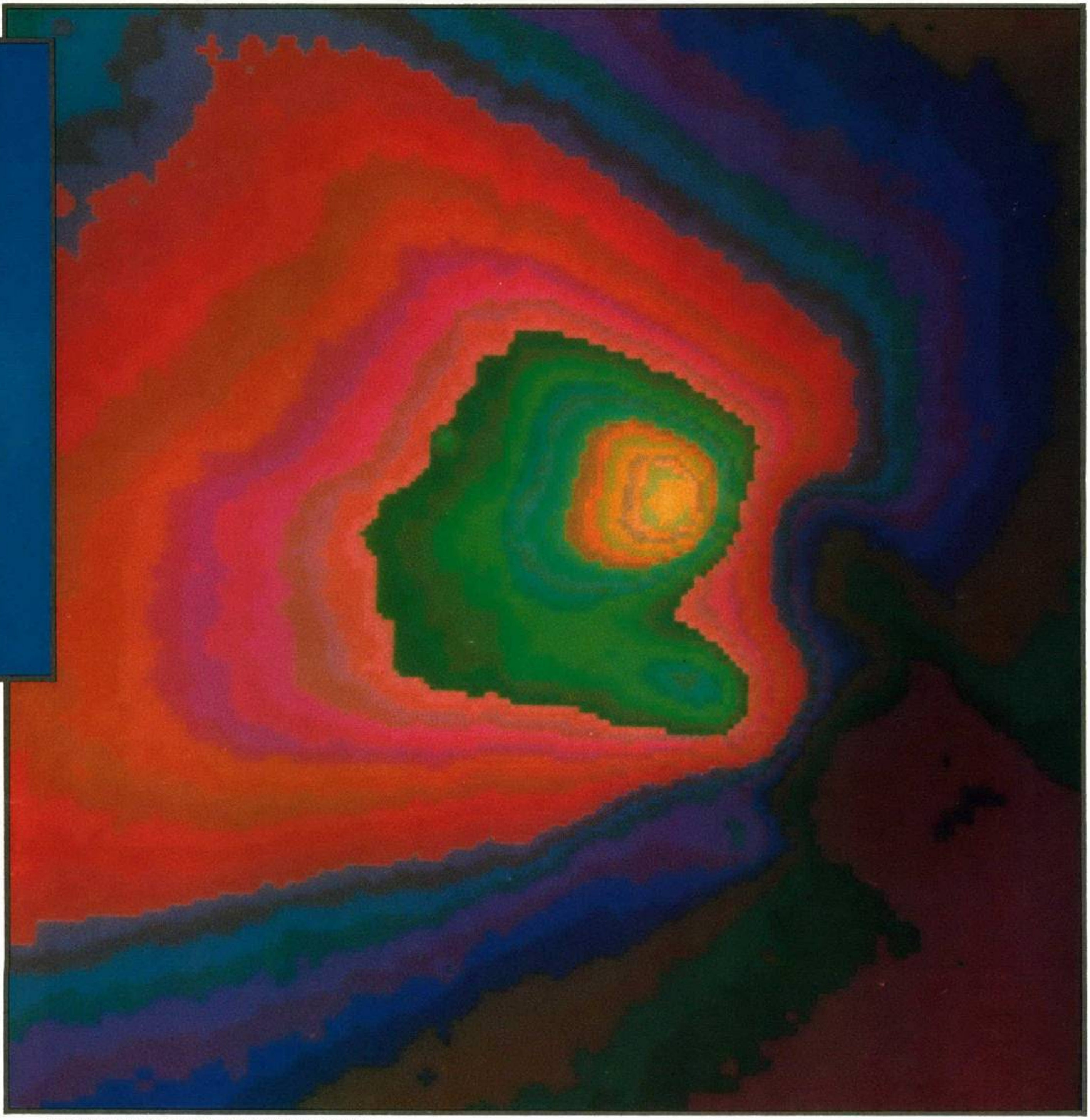
The Lightweight Nucleus

Silicate rock has a density of 3,200 kilograms per cubic meter, water ice a little under 950 kg/m^3. The density of the nucleus of Comet Halley lies somewhere between 100 and 400 kilograms per cubic meter: the nucleus is made of a very light material. Given the large uncertainty in the mass of the nucleus, astronomers might not have believed such a result had not other observations tended to confirm it.

The scientists operating the dust analyzers aboard Giotto, for example, reported the dust particles that impacted on their instruments were fluffy, low-density structures. The dust detectors found large numbers of very fine particles at large distances from Halley but not close up, which suggested that large, friable clumps of grains broke up as they moved away from the nucleus. The ground-based *detection* of cyanogen gas jets is also most easily explained by weak grains that break up as they move away from the nucleus.

Furthermore, some of the fine particles of dust collected by high-flying NASA research aircraft from Earth's upper atmosphere (known as Brownlee particles, or "comet dust") have an open, porous structure even after the particles have entered the atmosphere. If they are actual bits of cometary dust, as the name implies, then we already have tiny bits of comet materials in terrestrial labs, and even these samples, heated and degraded from their passage through Earth's atmosphere, are light and fluffy.

A less direct line of reasoning is based on the relatively large number of "lost" comets, splittings, and



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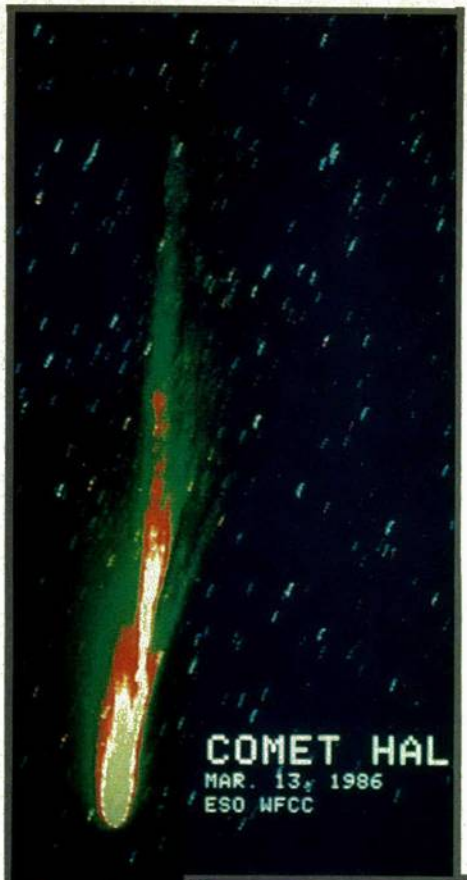

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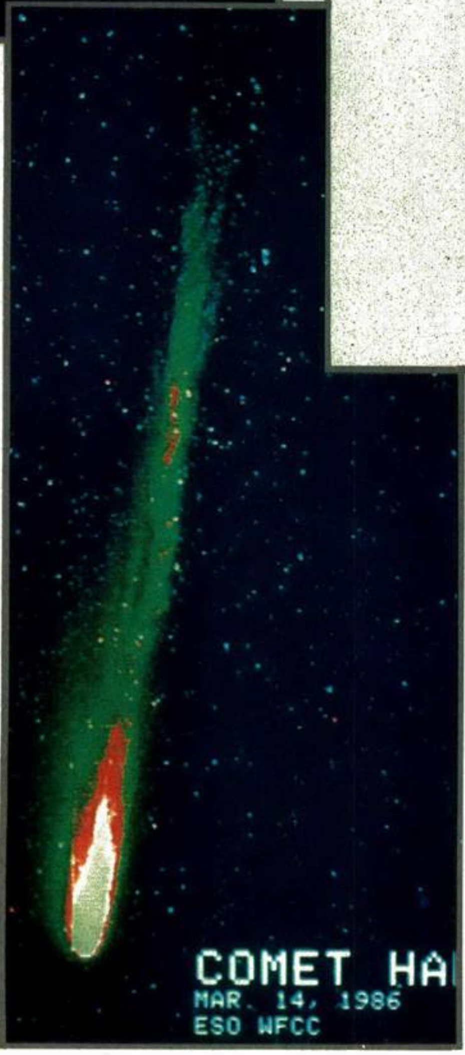

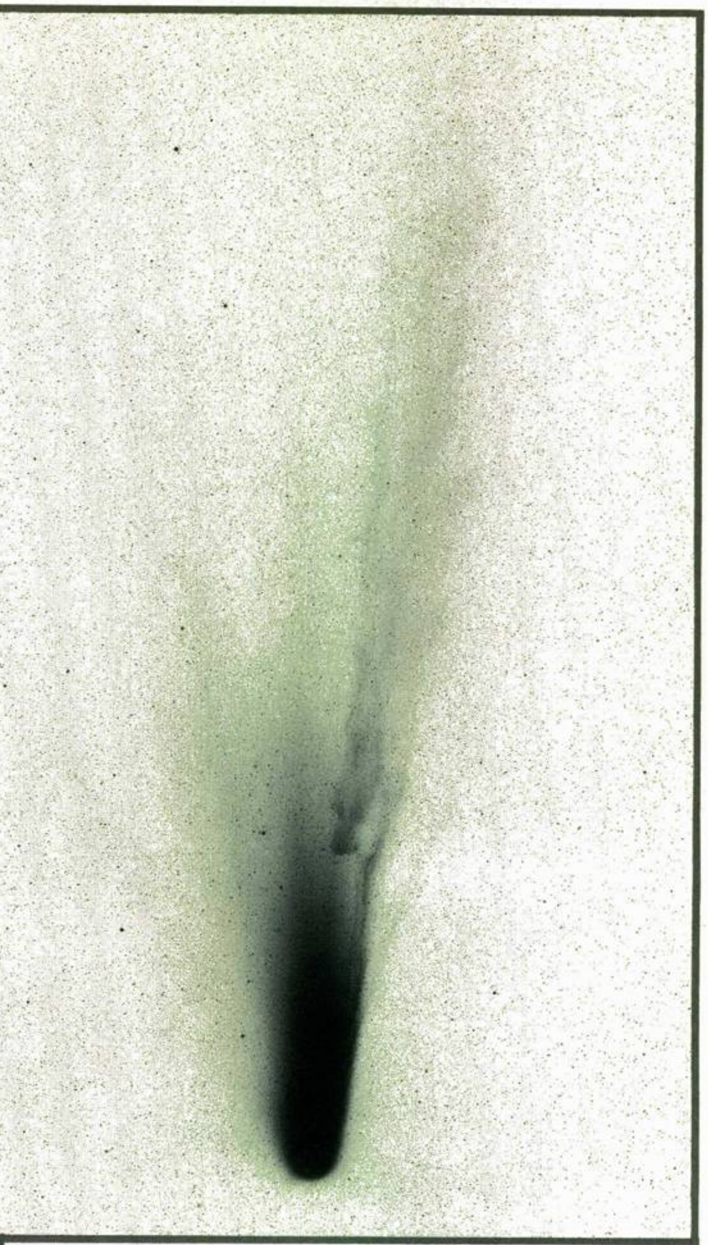

Left and top left: **Night-to-night changes seen in the tail of Comet Halley shed light on the interplanetary medium the comet moves through as well as on the production of gas by the comet itself. Taken in the light of ionized carbon monoxide, these pictures show material that was probably frozen carbon dioxide only days before.** Above: **Disconnection events, in which part of the gaseous coma surrounding the nucleus is blown down the tail, occur when a comet crosses a magnetic sector boundary in the solar wind.**

sudden outbursts. Astronomers have watched large comets fragment, have seen small comets split into pieces, and have observed starlike condensations near the nuclei of comets, which are presumably pieces breaking off the nucleus. All of this suggests that comets are structurally weak, which certainly does not contradict the notion that their nuclei are very light snowballs.

Disintegrating Fluffballs

Comets would have little value to astronomers if they were as inactive as other small bodies in the solar system. Indeed, they might not even have been detected, let alone recognized, as samples of the material from which the solar system formed. Asteroids as small as typical comet nuclei are difficult to detect; we know little about them

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because all we can observe is how they modify the sunlight they reflect. But comets call attention to themselves. A comet nucleus only a few kilometers across disintegrates before our eyes, grows a huge, glowing coma, and spreads a tail millions of kilometers long across the sky. Instead of seeing a passive, "dead" ball of ice, we see something that is literally blowing itself apart. Even a big comet like Halley's Comet will be gone, used up, in another thousand trips around the Sun.

What does this do for astronomers? As the nucleus decays, they can observe how it decays and what it decays into — and from that, figure out what it is made of and what the primordial stuff of stars and solar systems is. Without even leaving the ground, an astronomer can find out what gases make up the comet's tail. Relatively simple flyby missions like Vega and Giotto have already sampled material from a comet without having to return samples to Earth. Thus, comets yield an immense amount of information, albeit difficult to correctly interpret.

Ground-based astronomers can readily detect a variety of highly reactive radicals, molecular fragments like OH^+, CN^+, H^+, C_2^+, CO^+, CO_2^+ in the comet's tail. To determine what the parent molecules, present in cometary ice, might have been before they boiled into space, scientists have had to calculate backward using the reactivities and concentrations they could observe directly and making educated guesses about the concentrations of molecules that don't happen to fluoresce at wavelengths we can easily observe. Among the molecules that fall into this category are water, ammonia, methane, and carbon dioxide — all of the most likely candidates for cometary ice.

We now know something about the surface structure of the nucleus; what we really need to look at is the interior.

Elements and Isotopes

Giotto and the two Vega spacecraft carried mass spectrometers into Comet Halley to sample the cometary gas directly. They found that 80 percent of the comet gas is water vapor; 10 to 15 percent, carbon monoxide. All other gases total about 5 percent.

This was not unexpected. The elements that make water — oxygen and hydrogen — are abundant in the cosmos, so the water should have been there. Carbon, however, was deficient in comets, relative to the amount of oxygen in the solar system. This posed something of a mystery. If comet dust consisted of silicates (i.e., rock), then there should have been four times as much carbon in comet gases as had been observed. There were explanations that could somehow exclude carbon while including oxygen in a comet, but they were generally considered unsatisfactory.

But researchers were looking for something a bit more subtle. Simple comparisons of the abundance of one element with the abundance of another element are not sufficient to establish, say, that comets formed in the same giant molecular cloud that the rest of the solar system formed in. Chemical processes could have changed the ratios of the different elements present. However, the

Overleaf: **This dramatic photograph of Comet Halley was taken on February 22. It shows the comet in the dawn sky just two weeks after perihelion, near the time of its peak activity. The photograph, shown here as a negative to improve the rendition of the tail structure, is a 2-minute exposure with the 1.2-meter UK Schmidt telescope.**

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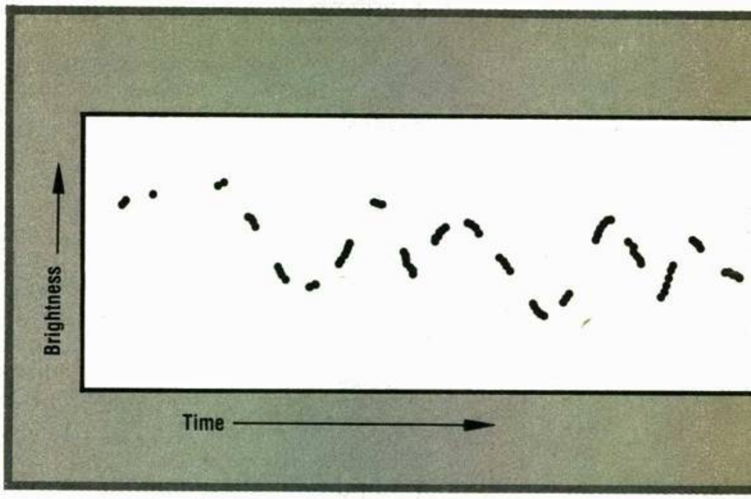


abundances of different isotopes of the same element vary from cloud to cloud. An isotope of an element has the same number of protons in the nucleus but a different number of neutrons. Because the isotopes of an element are chemically very similar, we would expect the pattern of isotope abundances in comet gas and dust to preserve an isotope abundance "fingerprint" of the comet's place of origin.

Mass spectrometers can distinguish between isotopes of the same element, and, indeed, establishing the pattern of isotope ratios was a major goal of the comet flybys. Although they were not determined with great accuracy, Giotto measurements of the isotope ratios C^{13}/C^{12} and N^{15}/N^{14} and S^{34}/S^{32} present in Halley's gases fall in the range astronomers expect for solar system objects. Comet Halley, therefore, probably formed in the same nebula that our Sun and its planets formed in.

The most important discovery about the dust is that at least some component of it is also a source of parent molecules.

Meanwhile, the missing carbon turned up not in the gases but in the comet dust. The dust mass spectrometers aboard Giotto and the Vegas found three types of dust particles. The first has a composition like that of the type C1 carbonaceous chondrite meteors, a rather rocky mix of magnesium, silicon, calcium, and iron, plus a carbon, hydrogen, oxygen, and nitrogen component of nonbiological organic compounds. Carbonaceous chondrite is considered a primitive meteoric material. (The Martian satellites Deimos and Phobos seem to be chondritic bodies.) The second type of dust is similar to the first but contains higher abundances of sulfur, carbon, and nitrogen.

The Dust Called CHON

The big surprise was the third type of dust, called CHON particles, which consists largely of carbon, hydrogen, oxygen, and nitrogen — in short, dust that isn't rocky at all. These four elements are important components of the icy satellites of the giant planets and the planets Uranus and Neptune.

The distinction between cometary gas and dust blurred with the discovery of CHON particles and then disappeared entirely with the discovery of cyanojets. Using a 24-inch telescope at Perth Observatory, astronomers photographed Comet Halley in the light of cyanogen, a simple molecule consisting of an atom of nitrogen and an atom of carbon. They used narrow-band filters to isolate the cyanogen light; their pictures were essentially maps of the distribution of this gas in the comet's inner coma. The images showed a spiral pattern of jets extending at least 50,000 kilometers from the nucleus.

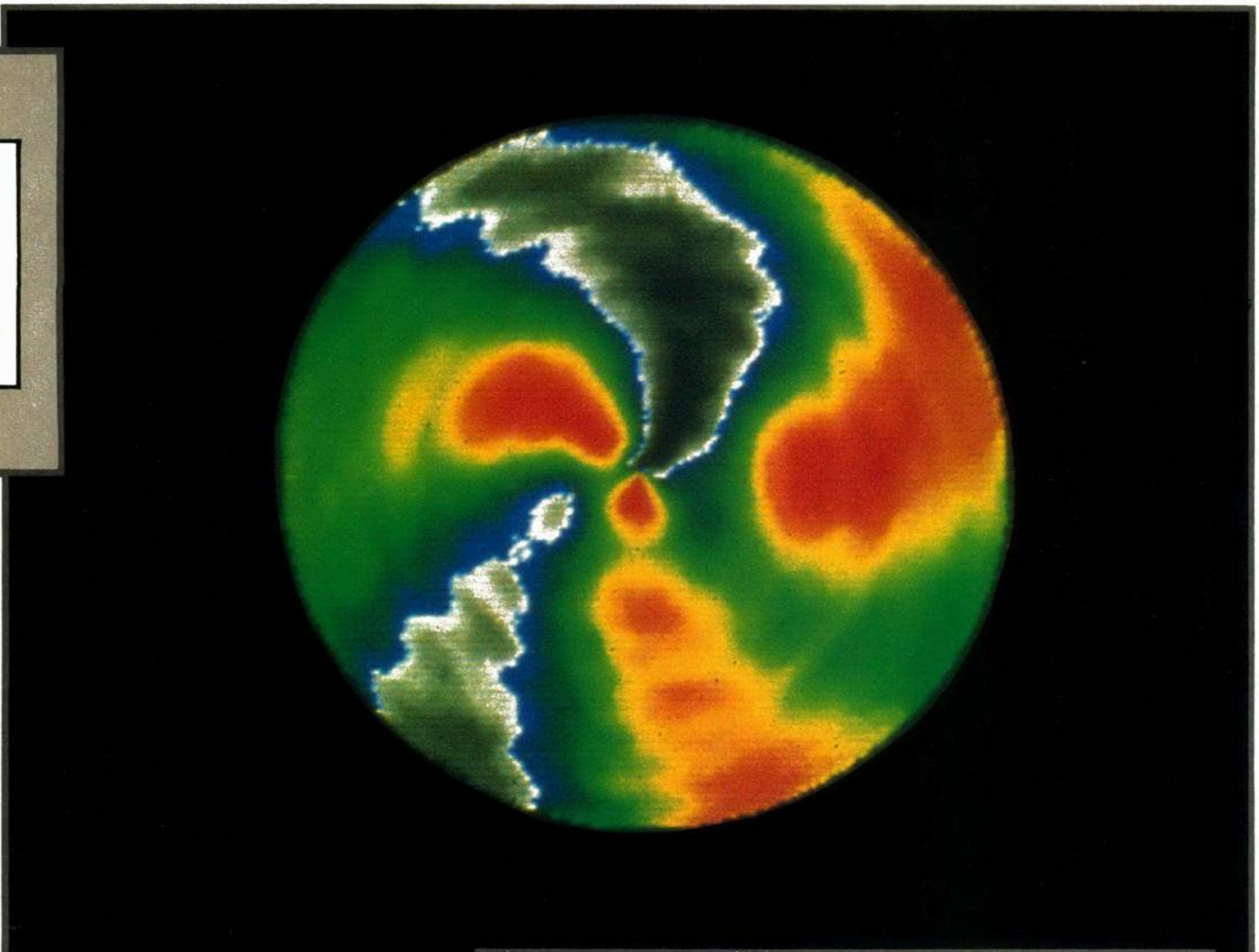
Cyanogen gas could not by itself form jets because it would spread much too rapidly through the near-vacuum of the inner coma. If the cyanogen came from the nucleus, it would form a haze all through the inner coma. The inescapable conclusion was that cyanogen was being generated from fine dust grains in the jets themselves. CHON grains are the obvious source: sunlight falling on them would break up the molecules in the CHON grains, liberating cyanogen gas.

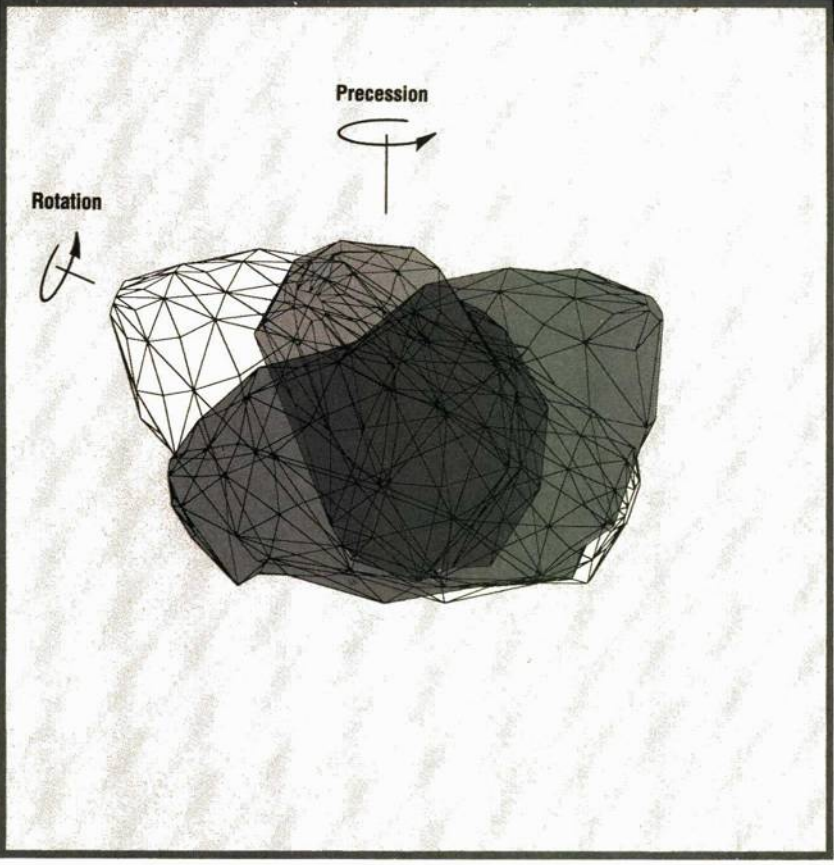
At a stroke, then, astronomers had strong evidence that at least one comet has the chemical and physical attributes expected if comets formed from the same material the Sun and planets formed from, that they formed rather far from the Sun out of essentially unmodified interstellar grains, and that the material appears to be pristine, modified only by being slightly compacted. As never before, NASA's long-delayed CRAF mission, which would fly to a comet, orbit it, and then fire a probe into the nucleus to measure the pristine interior, appears to be the vital next step in the exploration of the solar system.

Black Ice

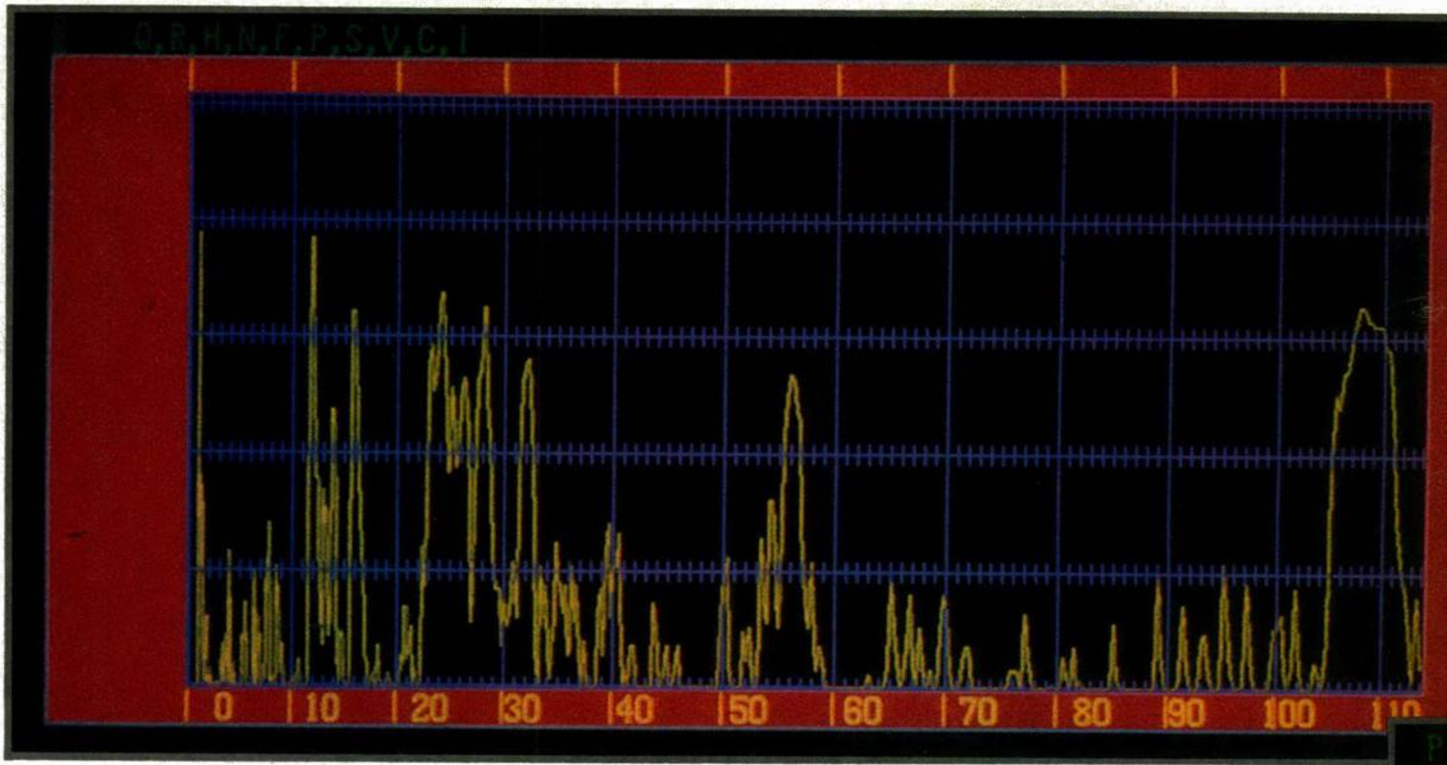
The blackness of Comet Halley's nucleus came as a surprise to the astronomical community; the very words "icy snowball" seem to have prevented the results that several groups of infrared astronomers had obtained from sinking into the minds of astronomers. Reflecting only 4 to 5 percent of the sunlight that fell on it, the nucleus was truly as black as soot. The surface was hot too. Of course, a black surface sitting in full sunlight *should* be hot, but few astronomers had expected Halley's nucleus to be black, let alone hot. Vega's infrared spectrometer actually measured its infrared emission and confirmed it really was hot. Yet Halley's overall production of gas was only one-tenth of what an icy body at that temperature should have been. Furthermore, virtually all of the gas and dust coming from the nucleus escaped from narrow jets, through holes or cracks in the surface.

This raised two questions: what is the hot, black crust





The rotation period of Comet Halley remains uncertain. Spacecraft images seem to show the nucleus rotating with a period of 2.2 days — in fact, according to imaging team scientists, no other period is possible. However, the brightness of the nuclear region fluctuates with a 7.4-day period (upper left) in the light of C_2 and CN ions. How can the nucleus spin with periods of 2.2 and 7.4 days? The cyanogen jets (above) also appear to rotate with a 7.4-day period. One solution *(right)* is that the nucleus precesses like a spinning top every 2.2 days and rotates about its long axis with a period of 7.4 days.



Above and lower right: **Mass spectra reveal the composition of comet dust. The spectrum above was obtained by the PUMA instrument aboard Vega 1 and shows a spectrum rich in magnesium (24), silicon (28), calcium (40), and iron (56), as well as hydrogen (1), carbon (12), nitrogen (14), and oxygen (16). The broad peak at mass number 107 is due to the silver "target" in the instrument. The mass spectrum at right is a CHON particle detected by Giotto's PIA instrument. Notice how simple this spectrum is: hydrogen, carbon, nitrogen, oxygen, and magnesium dominate it.** Top right: **Grains of interstellar material, shown schematically here, consist of a silicate core wrapped in a baked-on layer of hydrocarbon polymers, coated with a thin icy shell.**

on the surface of the nucleus, and where did it come from? The crust material is stable at high temperatures, black, and cohesive enough to resist the pressure from gas in the interior of the nucleus. The discovery of the CHON particles clinched the case: the nuclear crust is some kind of organic polymer, the baked-out remnant of the inner layer of hydrocarbon compounds present in interstellar dust.

From the looks of it, then, comets are just condensations from interstellar-type material that have been heated from the outside. Their activity, that is, their rate of outgassing, depends on how much solar heat can get through the crust to the volatile material inside.

The pristine material of the solar system has indeed been found. — *Fred Whipple*

Astronomers expect to find the interior partially differentiated. On top is the crust, baked dry and burned to a crisp. Underneath the crust is a layer of parboiled material consisting of rocky silicate grains, cores, carbon gunk, and water-ice minus any of the more volatile ices, and, deep inside, the volatile ices and exotic primitive materials.

The enormous variation in Comet Halley's level of activity suggests that the interior of the nucleus is not particularly homogenous. This squares with its being built up of small bodies from a few meters to a few kilometers in size, an icy conglomerate, made of materials that did not all come from the same region in the solar nebula.

It also implies that comets may be quite different from one another. If variations in the interior of one comet can produce day-to-day variations in its behavior, then the variation from comet to comet could be even more striking. One comet is not enough: we will need to sample many.

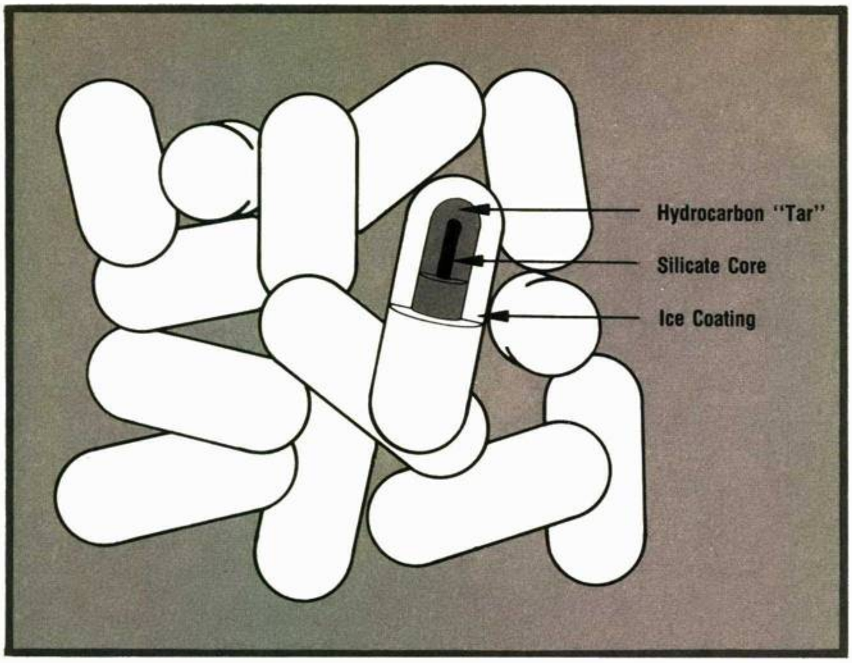
Dust to Dust

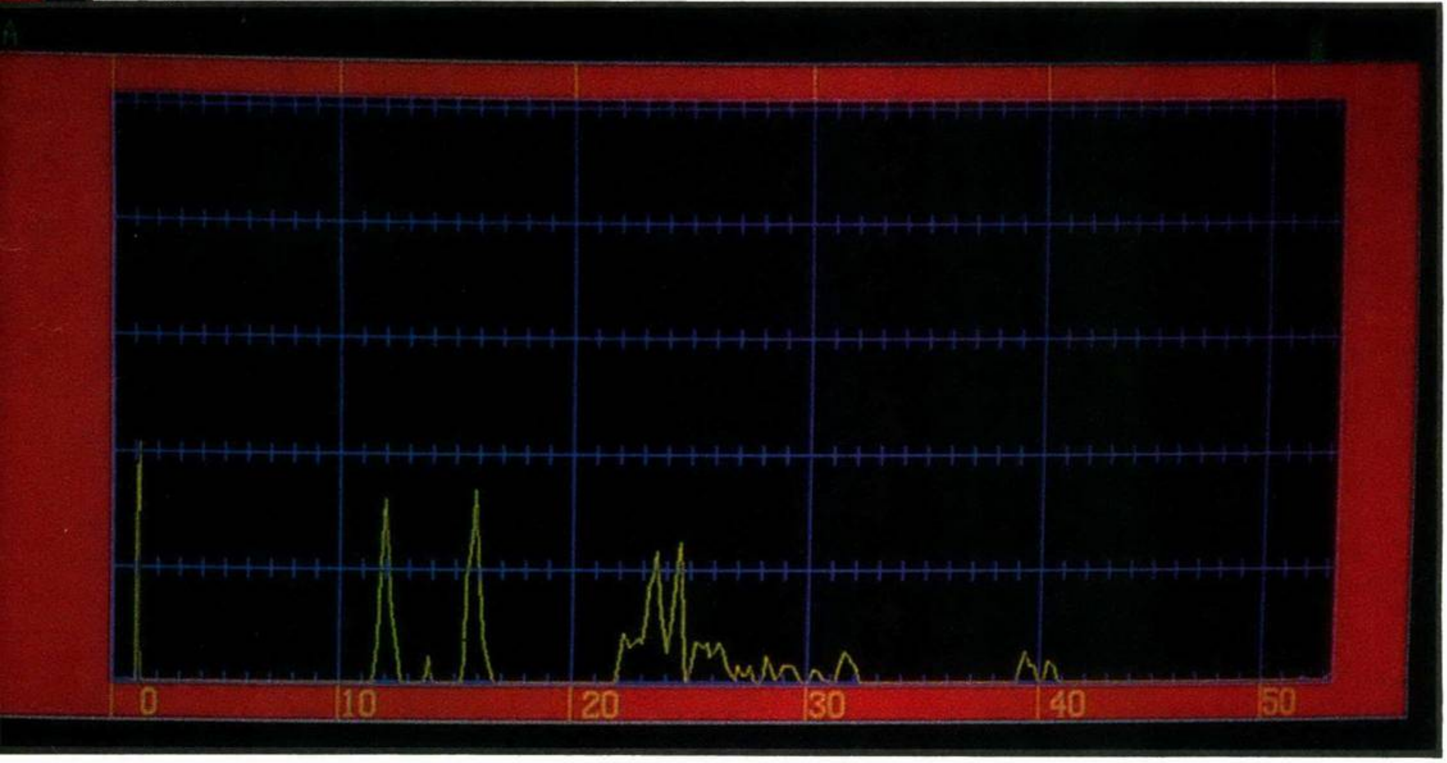
Halley's Comet began as no more than a few of these tiny grains of interstellar material stuck together, as minute spindles of graphite blown out of the atmosphere of a long-dead red giant star and coated with molecules of ice deep inside a giant molecular cloud. As time passed, dense regions of the cloud became even denser, and stars began to form.

One such star attracted a flattened pancake of gas and dust. At the center of this protostellar cloud the gas compressed, pulling more and more material into itself, and became hot. As the cold gas and solid grains orbited the protostar, they collided and stuck together in larger and larger lumps. Close in, the growing heat of the newborn star melted icy grains and drove gas away, so the planets that later formed from the orbiting grains were made of refractory rock. Farther out some ice remained, later to become the raw material of the gas giant planets. Growing lumps of ice and rock collided and stuck, and then collided in turn with other growing bodies.

At the outer edge of the system, far from the heat and light of the infant star and quite possibly beyond the outermost of the planets, collections of grains brushed other snowballs in gentle, almost "energyless" collisions. Countless numbers of cometesimals grew without slamming together, without melting, without violent change. Just a touch of gravity from the distant Sun held them, but when the star escaped its natal cloud, the cloud of comets went with it.

For a billion, two billion, then three billion years the comets spun slowly through space, sometimes coming a



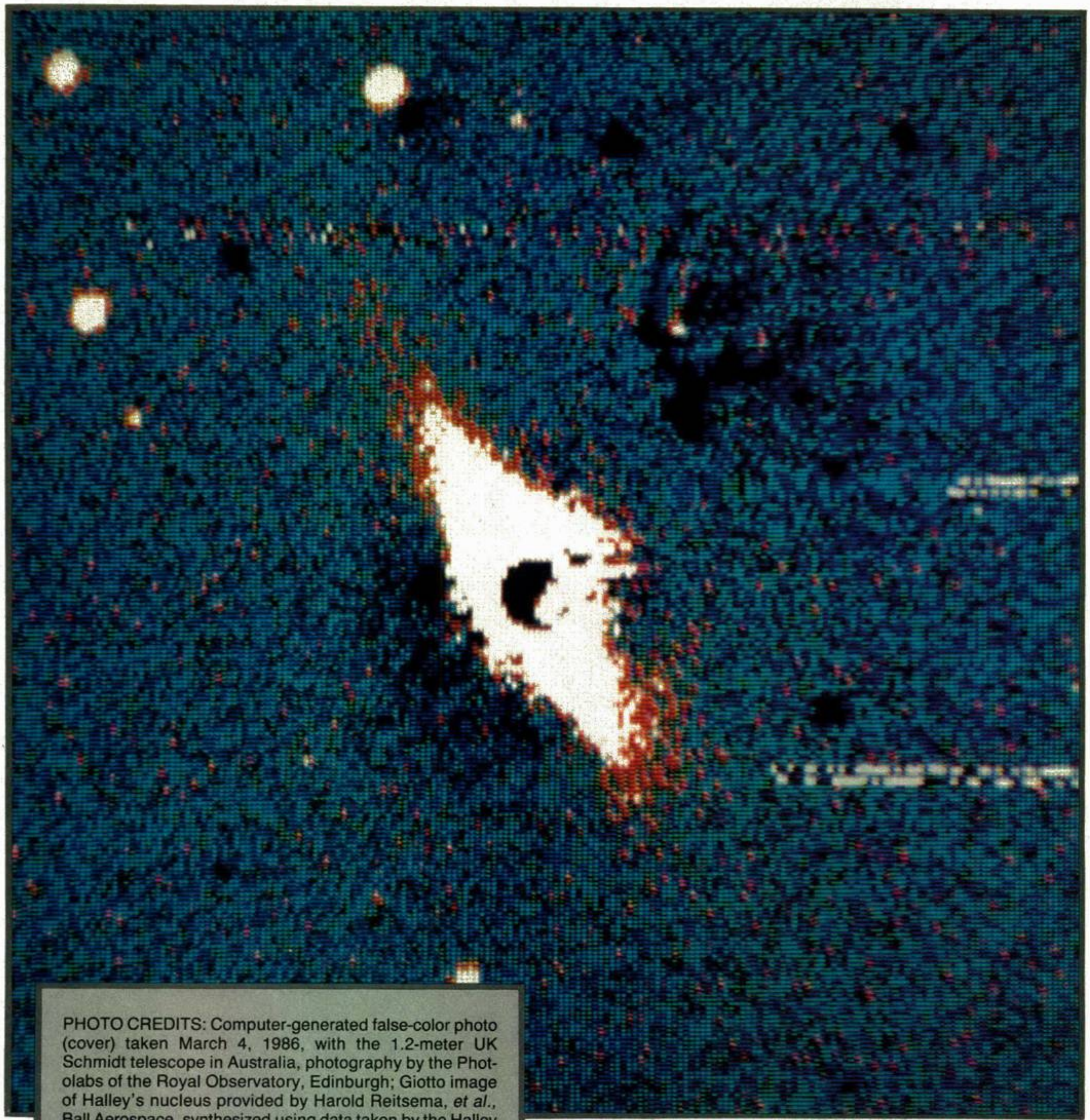


little closer, sometimes moving farther away in giant, lazy arcs. Only on the smallest scale was there any excitement: energetic cosmic rays bombarded the comets' surfaces, dumping millions of electron volts of energy into atoms bound by twos and threes and tens of electron volts.

> **The black surface really shouldn't have been a surprise — the infrared people were telling us that it was dark all along, but we weren't listening. — *Fred Whipple***

Another billion years passed. Broken chemical bonds welded small fragments of organic molecules into bigger molecules, and those in turn into tarlike polymers. Slowly but surely the icy surface of the comet nuclei turned yellow, then brown, then black.

We may never know exactly which twitch in the gravitational forces nudged one of these little bodies away from its quiet orbit in the Oort cloud — but the comet's first pass near the Sun must have been spectacular. Exposed to heat for the first time in 4 billion years, the irradiated ices virtually exploded, releasing energy trapped for millennia, spewing icy grains and volatile ices into the brightest coma and the longest tail Halley would ever produce. But the solar heat took its toll: as Halley plunged toward the Sun again and again, a dense mantle of ice formed, and a layer of heat-resistant organic residue built up on the surface.



Is Beta Pictoris a "solar" system in formation like our own Sun 4.6 billion years ago? This star lies at the center of an edge-on disk of dust grains with a mass approximately that of the planet Jupiter. The disk is 400 astronomical units across, far larger than our own solar system. If Beta Pictoris has planets, and they lie at distances comparable to those in our own solar system, then they are too close to the star for us to detect with present technology.

Several thousand orbits later, Edmond Halley realized one historical comet had come back again and again. He predicted the date of its next return, and though he did not live long enough to see it, he was correct in his prediction. Then, in March 1986, five spacecraft greeted the comet, sampled its gases and dust, and took some pictures.

Halley's secret is no longer a secret: it and comets like it are the solar system's only remaining primitive bodies. They hold clues to the origin of our Earth, of our solar system, and of our star. We have a lot to learn from them.

PHOTO CREDITS: Computer-generated false-color photo (cover) taken March 4, 1986, with the 1.2-meter UK Schmidt telescope in Australia, photography by the Photolabs of the Royal Observatory, Edinburgh; Giotto image of Halley's nucleus provided by Harold Reitsema, *et al.*, Ball Aerospace, synthesized using data taken by the Halley Multicolor Camera, Dr. H. U. Keller, principal investigator, Max-Planck-Institut fur Aeronomie; negative print (page 7) from a 40-minute exposure taken April 14, 1.2-meter UK Schmidt; computer screen images (pages 8, 9, 10, 11) courtesy G. A. Avenesov *et al.;* Suisei photographs courtesy European Space Agency; Giotto images (page 13) courtesy ESA, by the Halley Multicolor Camera, Dr. H. U. Keller, principal investigator, Max-Planck-Institut fur Aeronomie; color images (page 14) courtesy European Southern Observatory; negative prints (pages 14 and 15) taken March 9 and 10 and February 22 (pages 16 and 17) by the 1.2-meter UK Schmidt telescope, courtesy Royal Observatory, Edinburgh; light curve (page 18), courtesy R. L. Millis and D. G. Schleicher, Lowell Observatory; cyanogen jets (page 19), courtesy Michael F. A'Hearn, *et al.*, University of Maryland, Perth Observatory, and NASA-Goddard Space Flight Center; mass spectroscopy (pages 20 and 21) by the Giotto PIA and Vega PUMA groups, courtesy ESA; Beta Pictoris (page 22) Bradford Smith and Richard Terrile, University of Arizona/JPL.

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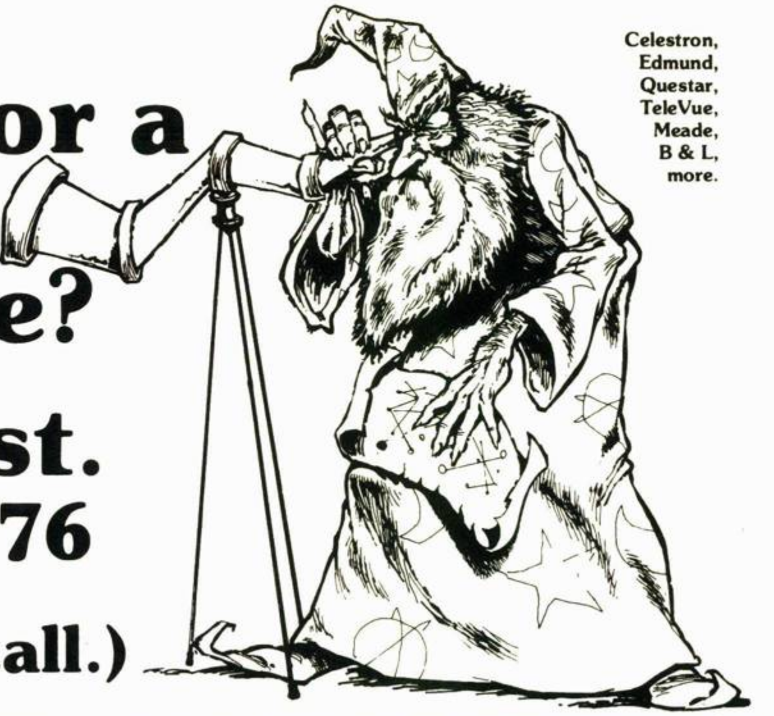

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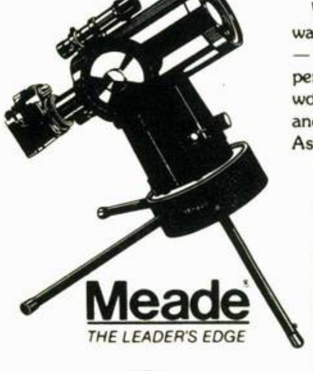

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Summer Reverie with Cygnus Overhead

That summer I worked four jobs. Every day was spent speeding from one job to another and, of course, working. I had no social life. At the end of each day I was exhausted. My life was one big schedule. By the time I went on vacation at the end of August I couldn't even remember what a day was like without shifts.

That vacation was heaven — one week of simple camping and selfish laziness. One evening as the sinking Sun streaked the blue sky with gold and red, I dragged my gear down the long wooden dock and pushed my boat out into the still water, heading for the center of a small, shallow lake. The firmament darkened as my toylike plastic oars chopped the surface of the reflecting water. When I reached my destination, I softly anchored my craft in the silence that made me believe I was the only sentient being in a remote and separate world.

I dropped a hooked worm into the water, positioning the pole between my feet as I lay back to observe the stars brightening. On the cassette player a classical guitar played techno-rock with pastoral overtones unlike those of Beethoven.

Gazing at the Milky Way as it stretched from horizon to horizon I remembered the first time I had seen it. I was a Boy Scout setting up a tent west of Chicago on a Friday night. I stared at the dark sky in awe — I had never seen so many stars before. I focused on the milky band of light overhead: it must be made of millions of stars, I figured, each a member of our Galaxy. Without knowing I was correct, I ran around from scout to adult asking if my theory was accurate. I was told to go and set up my tent.

A shooting star, a mere speck of dust vaporizing from friction as it fell through the atmosphere, brought me back to the lake.

Directing my gaze along the southern horizon, I greeted Sagittarius the Archer. Farther out, behind this constellation, is the mighty core of our Galaxy, hidden by the gas and dust that float between the stars.

I tilted my head back to view muscle-man Hercules and Cassiopeia the queen. M-31, the Andromeda Galaxy, which is near Pegasus the Flying Horse, caught my attention, and I remembered it was the most distant naked-eye object — some 2.2 million light-years away! I wondered if any creature in the Andromeda Galaxy was gazing at the Milky Way, thinking thoughts like mine.

A dim spot of sunlight glinted off a satellite that was passing overhead. Was it a spy satellite? As I traced its heavenly path the last song on the cassette, "Cygnus X-1," echoed in the silence of the night.

I moved my head to face the zenith and viewed the majestic swan, Cygnus, against the lighted background of the Milky Way. The story of the song unfolded.

A man in a spaceship called the Rocinante is heading east of Lyra, flying into the light of Deneb. The ship is sailing across the Galaxy, headed for the black hole Cygnus X-1.

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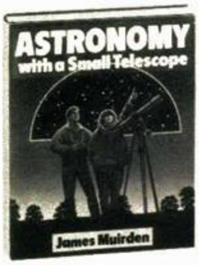
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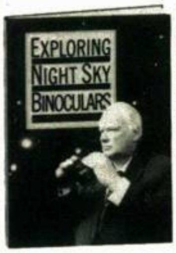
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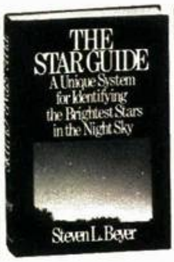
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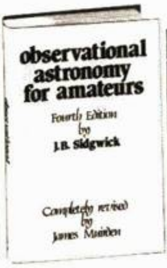
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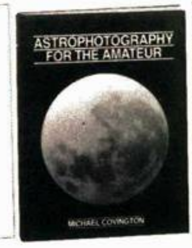
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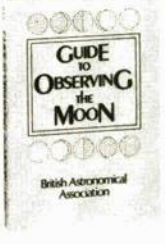
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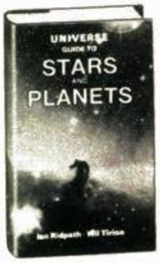
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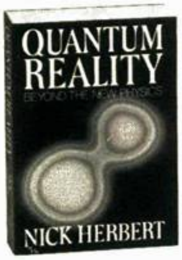
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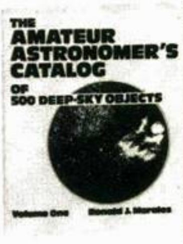
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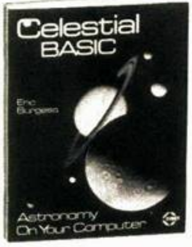
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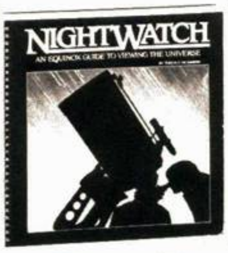
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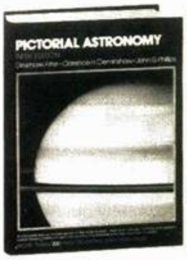
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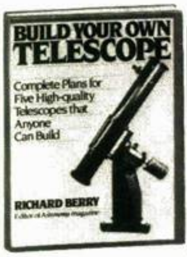
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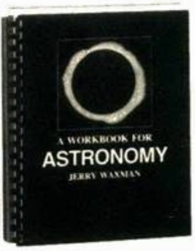
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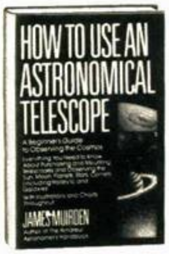
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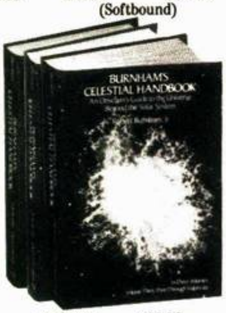
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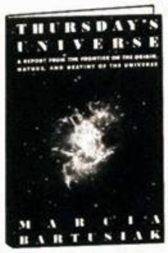
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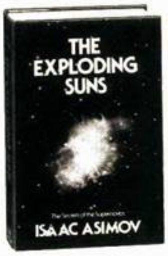
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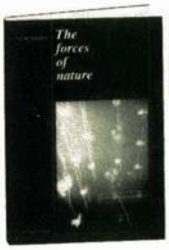
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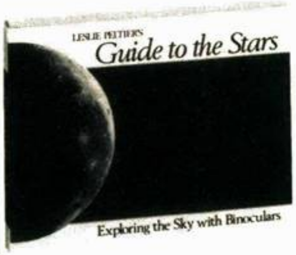
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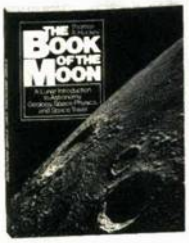
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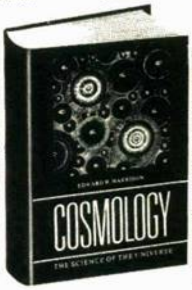
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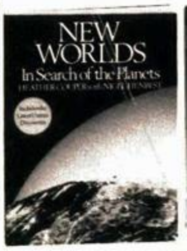
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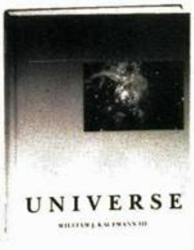

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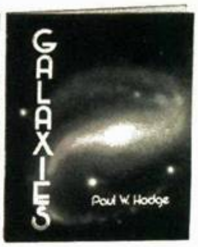
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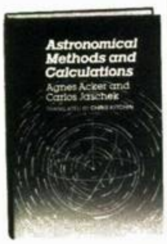
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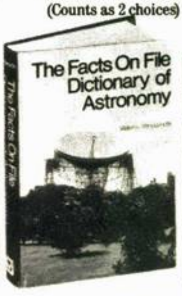
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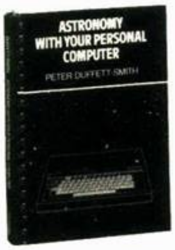
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Instantly I accelerated toward it, past other stars. Cygnus became so near it engulfed my field of view. Suddenly the Rocinante jerked and started to spin as it fell fast at Cygnus X-1. The whole sky was whirling! I was viewing a quick-spinning obscurity and the entire world was blowing up! I tried to scream but nothing came out.

The song ended. I gradually returned to reality. The dark lake materialized and I could hear frogs croaking. The cool air wisped by me. I collected my equipment, took one last look at Cygnus peacefully soaring overhead, and headed for shore.

I slept in the back of the van, underneath the window. As I lay in my sleeping bag I realized that I didn't catch a single fish. But it didn't matter. I had traveled to the heart of Cygnus.

Through the darkness, beyond my closed eyes, the starlight must have revealed my sleeping smile.

Joseph J. Falout
Woodridge, IL

Astronomy on the Open Road

Scorpius may be up by now. I might be able to see it over on the right side of the van as I drive past the glaring lights of Opelousas — if the trees weren't in the way and if the sky in southern Louisiana weren't so murky.

Seeing Scorpius is pretty hopeless right now. Not just because the road winds too much and too many lights are reflected off the windows, but because I also have trouble finding the constellation.

My attention shifts to finding the Bears and the pole star through the windshield. Headlights. At this rate the only bears I'll be seeing this morning will be wearing badges and driving automobiles with blue and red lights on the roof.

I might be able to make some sense of the stars if I had Tom Hebert in the passenger's seat.

Tall lanky Tom, the knockabout electrician. My mentor on matters astronomical. The guy responsible for my stargazing on clear nights when I'm out on the road and bored out of my skull.

Calling Tom my mentor is probably a disservice to him. I have trouble isolating patterns of stars, I get the patterns backward (I'm a bit dyslexic), and I forever confuse names, dates, and facts. I am not good material to work with.

That I am able to even fumble through the night sky is a great credit to Tom. But then he has motives different from mine for wandering outside on clear nights, looking up, and watching the show. I am a hedonist, and stargazing is just another of life's pleasures. I'll never advance much beyond "Backyard Stargazer — Third Class."

Tom is different. He has been pursuing his interest in astronomy since he was a teenager — back in the mid-sixties — and is addicted to clear nights and fine periodicals and books on astronomy. It isn't idle curiosity that keeps him addicted. His addiction goes much deeper than that and is rooted in too fertile a soil. And the yield is too rich.

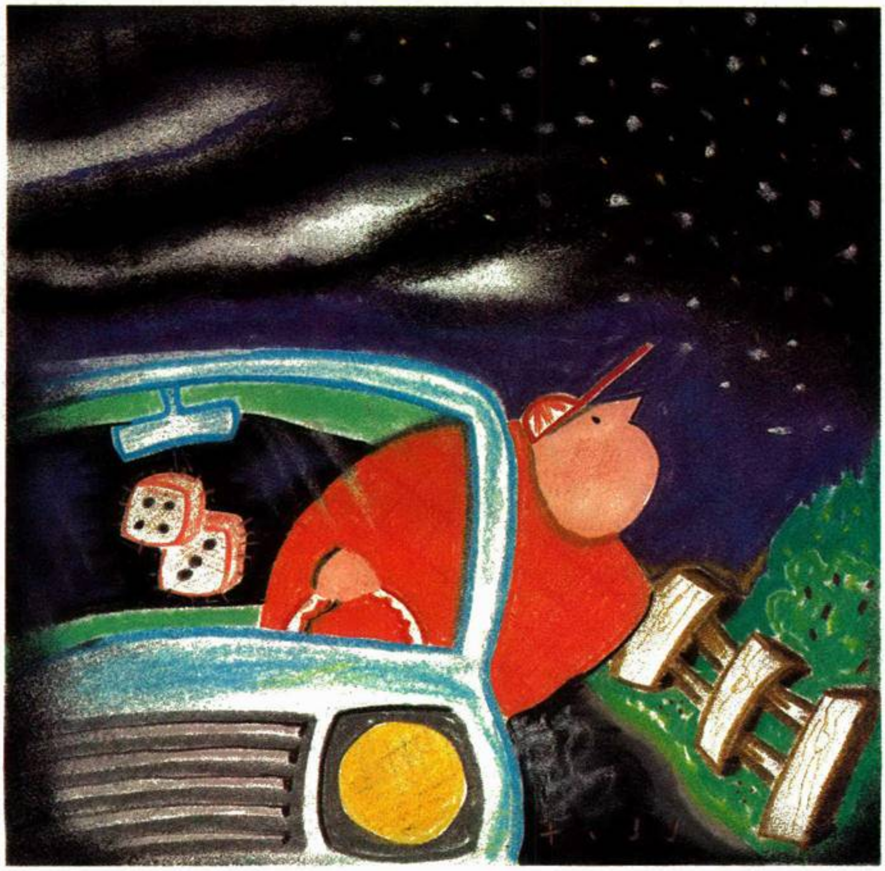
Tom would no doubt be embarrassed even by the suggestion that love is the reason he's involved with astronomy. Maybe this is because our society has a rather myopic notion that love is appropriate only between people. But, because love is a positive emotion, it does seem reasonable to assume that a great benefit would come from loving grandly.

Few things command attention on as grand a scale as astronomy, which takes in all of the observable universe and figures prominently throughout history. There are remnants of events to gaze upon that involve the eyeblink conversion of solar systems into dust, junk, light, heat, and lots of radio static. There are also unseeable objects that release more energy than whole galaxies to puzzled electronic ears. To the uninitiated these are strange things, disturbing and troubling. To Tom these are subtle points of interest in a comfortable old neighborhood becoming even more comfortable as the years pass.

The names Bruno, Kepler, Foucault, Messier, Herschel, Michaelson, Hubble, Humason, and Shapley are not merely entries in an encyclopedia but the names of friends he has encountered over many years of reading. The history of astronomy has a special magic that Tom conveys with the same sonorous, easy-going manner he uses when he chants the positions of constellations, stars, Messier objects, and planets.

In fact, there are times I can almost see him, not out in front of his old rented farmhouse but in a clearing near Athens around 700 or 600 B.C. The clothing would be different. His words would be incomprehensible to me, but I'm sure he'd use his customary informal and colloquial manner no matter how complex the discussion. At thirty-three he'd be entering respectable middle age, and since folks such as Volta, Watt, and Tesla would be little more than random molecules awaiting assembly, Tom would certainly not be rewiring houses for a living. Very likely he'd earn money from students who wanted to learn about the sky. That would be an ideal situation for Tom — being paid for what he'd gladly do for free.

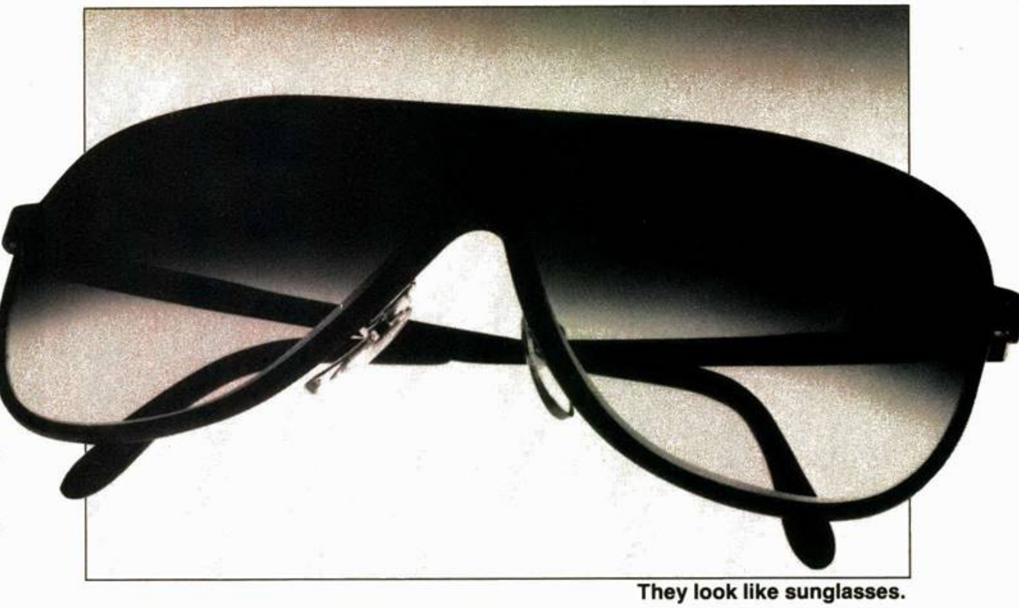
Sometimes I wish Tom belonged to another time. People can no longer wander in from nowhere as Milton



Todd Graveline

Vision Break-through

When I put on the pair of glasses what I saw I could not believe. Nor will you.



They look like sunglasses.

By Joseph Sugarman

I am about to tell you a true story. If you believe me, you will be well rewarded. If you don't believe me, I will make it worth your while to change your mind. Let me explain.

Len is a friend of mine who has an eye for good products. One day he called excited about a pair of sunglasses he owned. "It's so incredible," he said, "when you first look through a pair, you won't believe it."

"What will I see?" I asked. "What could be so incredible?"

Len continued, "When you put on these glasses, your vision improves. Objects appear sharper, more defined. Everything takes on an enhanced 3-D effect. And it's not my imagination. I just want you to see for yourself."

When I received the sunglasses and put them on I couldn't believe my eyes. I kept taking them off and putting them on to see if indeed what I was seeing through the glasses was indeed actually sharper or if my imagination was playing tricks on me. But my vision improved. It was obvious. I kept putting on my cherished $100 pair of high-tech sunglasses and comparing them. They didn't compare. I was very impressed. Everything appeared sharper, more defined and indeed had a greater three dimensional look to it. But what did this product do that made my vision so much better? I found out.

DEPRESSING COLOR

The sunglasses (called BluBlockers) filter out the ultraviolet and blue spectrum light waves from the sun. You've often heard the color blue used for expressions of bad moods such as "blue Monday" or "I have the blues." Apparently, the color blue, for centuries, has been considered a rather depressing color.

For eyesight, blue is not a good color too. There are several reasons. First, the blue rays have one of the shortest wavelengths in the visible spectrum (red is the longest). As a result, the color blue will focus slightly in front of the retina which is the "focussing screen" onto which light waves fall in your eye. By eliminating the blue from the sunglasses through a special filtration process, and only letting those rays through that indeed focus clearly on the retina, objects appear to be sharper and clearer.

The second reason is even more impressive. It is not good to have ultraviolet rays fall on our eyes. Recognized as bad for skin, uv light is worse for eyes and is believed to play a role in many of today's eye diseases. In addition, people with contact lenses are at greater risk because contacts tend to magnify the light at their edges thus increasing the sun's harmful effects.

Finally, by eliminating the blue and uv light during the day, your night vision improves. The purple pigment in your eye called Rhodopsin is affected by blue light and the eyes take hours to recover from the effects.

SUNGLASS DANGER

But what really surprised me was the danger in conventional sunglasses. Our pupils close in bright light to limit the light entering the eye and open wider at night—just like the aperture in an automatic camera. So when we put on sunglasses, although we reduce the amount of light that enters our eyes, our pupils open wider and we are actually allowing more of the blue and ultraviolet portions of the light spectrum into our eyes.

BluBlockers sunglasses are darker at the top to shield out overhead light. The lens used is the CR-39 which most eye doctors will tell you is one of the finest materials you can use for glasses and is manufactured under license.

The frames are some of the most comfortable I have ever worn. The moulded nose rest will fit any nose. The hinge causes the frames to rest comfortably on your face and can be adjusted for almost any size face.

We also have a clip-on pair that weighs less than one ounce. Both come with a padded carrying case and an anti-scratch coating.

I urge you to order a pair and experience the improved vision. Then take your old sunglasses and compare them to the BluBlockers. See how much clearer and sharper objects appear with BluBlockers. And see if your night vision doesn't improve as a direct result. If you don't see a dramatic difference in your vision—one so noticeable that you can tell immediately, then send them back anytime within 30 days and I will send you a prompt and courteous refund.

DRAMATIC DIFFERENCE

But from what I've personally witnessed, once you use a pair, there will be no way you'll want to return it.

Astronomers from many famous universities wear BluBlockers to improve their night vision. Pilots, golfers, skiers, athletes—anyone who spends a great deal of time in the sun have found the BluBlockers indispensable.

Our eyes are very important to us. Protect them and at the same time improve your vision with the most incredible breakthrough in sun glasses since they were first introduced. Order a pair or two at no obligation, today.

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Humason once did and carve a niche for themselves. Professional astronomy is dominated by heavy-duty Ph.D.'s. Those who have the same desire to search the heavens but lack the proper credentials must satisfy their needs at their own expense in backyards or nearby fields, alone or in small groups. Their equipment is humble in comparison to that of the pros, which makes many amateur astronomers think that their astronomy lacks significance. A few nights out nosing through whatever's up in the sky with Tom would end that kind of thinking.

For the longest time I'd thought astronomy was something you did with a telescope. I was wrong. A scope is a nice thing to have, but astronomy goes beyond the equipment to the head and the heart. And Tom knows it.

Of course, if he knew it also meant helping me spot stars while lurching down a dark, twisting country road at fifty-five miles an hour, he probably wouldn't want to ride with me.

Bob Aiken
Duson, LA

A Telescope Worth Every Penny

"Do you always enjoy your work?" the reporter asked the astronomer as they jostled up the rugged trail in the old four-wheel drive pickup. "Don't you get lonesome up here on the mountain for days at a time?"

"You get used to it, Tom," the bearded astronomer said.

Tom had asked the question more for himself than for his story. *He* was lonesome, even when he was in the newsroom surrounded by hustling reporters.

Tom turned his attention to the observatory, now coming into view at the top of the mountain. The sight of the observatory aroused something deep inside him — something way down, buried for years and years — now suddenly demanding attention.

"Control, Tom," he told himself. "Don't let yourself feel guilty about the telescope."

Tom turned away from the disturbing thought to concentrate on the wrenching pain in his lower back as the truck lurched up the mountain trail.

"This is really hell for my back," he said to the astronomer. "I think I'm screwed up from all the driving I do on this job."

"You're lucky," the astronomer said. "When this observatory was first built, things were hauled up here on the backs of mules."

"I wouldn't last five hundred feet," Tom said. "Judging from how my back feels, I'm probably a reincarnation of one of those mules."

A numbing sensation gripped Tom's body when they pulled up near the observatory.

"What's going on here?" Tom thought, feeling the numbness and a shaking weakness. "It must be the thin mountain air."

The astronomer didn't notice Tom's hesitance to get out of the pickup. It was dark now and the astronomer's head was cocked upward as he walked to the observatory door. He was getting an overview of the sky before probing more intricately with the massive telescope.

The astronomer was already inside the observatory making preparations when Tom finally got out and walked toward the door. But his surroundings were becoming increasingly unreal: the dull red glow pouring from inside the observatory looked eerie and surreal, the thin mountain air was difficult to breathe and felt alien.

Stepping inside the observatory, he was overpowered at the sight of the huge telescope. The astronomer was speaking to him and Tom heard himself answer, but the exchange sounded like the muffled words of two people conversing in another room. Something extraordinary was happening to him. He felt out of control, like a log being carried down a rushing river.

Looking past the astronomer's dark figure, Tom saw a narrow slice of stars outlined by the observatory dome opening. In the middle of the starry slice the Pleiades floated serene and inviting.

The sight of the Pleiades completed the spell. Reality was suspended — the observatory, the soft voice of the astronomer explaining his work, and the chill of the cold mountain air — everything faded away. Only the Pleiades remained. Even the stars around them had gone black.

A voice spoke to him from far away . . . a voice trying to wake him from a deep slumber. It wasn't the astronomer's voice but one he hadn't heard in a long time. A young, excited, familiar voice.

"What do you see, Tom? What does it look like? Is it neat? Can I see now?"

Finally looking away from the Pleiades, he discovered he wasn't in the observatory anymore. He was outside but not on the top of a mountain. He was standing in grass that needed mowing. The thin, cold air of the mountain had been replaced by the soft, warm air of a September night. Looking around he recognized the familiar backyard of his parents' house in Minnesota. He was standing beside the new 6-inch Newtonian reflector his parents had begrudgingly bought him after he had begged for years. He smelled the newness of the telescope — a remarkable, exhilarating smell.

"What does it look like, Tom," the voice said again. He noticed the eager face of his little brother, who stood next to him.

"They're beautiful," Tom answered, deciding to participate in this familiar looking dream. "They're unbelievable. The Pleiades are like blue flames — like diamonds on fire!"

My little brother's eyes widened.
Flaming diamonds!

The telescope was everything Tom had ever wanted. It was the only thing he had dreamed about in the years since he had outgrown the toy, 3-inch reflector he got for Christmas years ago. But the new telescope came at a heavy price — guilt, lots of guilt.

It had cost his parents a lot of money, and they never let him forget it. Two hundred and fifty dollars plus fifty dollars for shipping.

"Well, Merry Christmas," his mother had said to him when the telescope was finally delivered from New Mexico in July. "I sure hope you appreciate it. This is a lot of money to spend for something like this."

His oldest brother had sided with his mother.

Tom Hunt

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(Shown with optional 8 x 50 finder)

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Ask about optional Optical Coatings & Electronic Drives!

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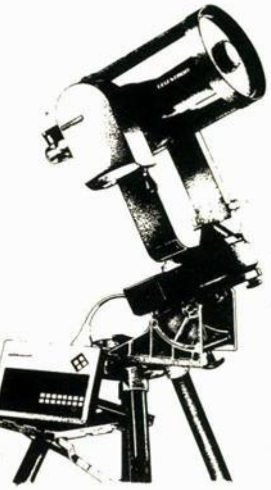
Ask about optional Declination and Focusing Motors!



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"Why spend all that money on that thing?" he said. "Tom will use it for a while and then lose interest in it. It'll just sit there and collect dust and you'll be out of a chunk of money."

But Tom persevered and got his telescope anyway — along with a generous serving of guilt. With guilt came the pressure to perform. He must use the telescope, appreciate it, and make it worth every single penny!

So use it he did. Every clear night, all night with the mosquitoes of summer and the bitter cold of winter. He had to satisfy Mom and prove his brother wrong.

Burnout came quickly along with confusion.

He loved the stars, but the grueling observing schedule soon became an exhausting obsession. The attempts to prove enthusiasm for the telescope became twisted sessions of negative reinforcement.

The beauty of the sky became secondary. He had to make sure the telescope wasn't a waste of money!

He came to dread clear nights and even prayed for cloud cover. Soon the telescope sat idle, collecting dust just as his brother had said it would. Guilt doubled.

Somewhere along the way he had lost the stars — he still loved them — but he could no longer pursue them. The stars had come to be associated with exhaustion and fear of failure — something he didn't understand consciously but something that happened nonetheless. All he knew was that the stars no longer belonged to him. The reasons were lost along the way. What remained were confusion and guilt.

Tom awoke to find himself flat on his back. He opened his eyes and blinked away tears, focusing on the Pleiades almost directly overhead.

"You okay, Tom?" the astronomer said. "Can you hear me?"

Tom saw the stars blotted out by the dark shape of the astronomer's head above him. Then a blazing light shown in his face. He clenched his eyes shut and lifted his hand to cover his eyes.

"Yup, you're awake," the astronomer said.

"Am I on the mountain?" Tom asked, bewildered.

"You bet you are," the astronomer said. "You wandered outside. I've seen this before. People think they can just move around the way they always do and then — wham! — the thin air shuts them off and they drop like flies. You've got to take it easy until you get used to the air up here."

Tom heard the astronomer's voice as he became awake. He took a deep breath of the brisk air and felt a mild exhilaration.

"As soon as you feel like it, we'll drive back down."

"No!" Tom said, nearly shouting to interrupt the astronomer.

"I'll be all right in a minute. Let's stay up here. The stars are very beautiful tonight. Go on with your observations. Besides, I'd like to peek through that big scope of yours."

"Well, if you're sure," the astronomer said, smiling at the reporter as he helped Tom to his feet.

"By the way, how much did it cost to build this thing up here?" Tom asked the astronomer as they walked arm-in-arm to the observatory.

"Millions, I guess," the astronomer said. "Come on, I'll show you the Pleiades — then you'll realize what a bargain we got."

"I'm sure I will," Tom said. He felt lighter somehow.

Ken Korczak
Inver Grove Heights, MN

'A Tell-Tale Tail'

Back in the fall of 1985, when Halleymania was sweeping the world, I was slowly but irrepressibly pulled in by the enthusiasts gravitating together to witness this celestial nomad. The closer Halley came to the Sun and Earth, the more coverage the media gave it, and the more my interest in this once-in-my-lifetime event was piqued.

I renewed my long-lost interest in astronomy: I joined Cleveland's Cuyahoga Astronomical Association and subscribed to ASTRONOMY. I bought a camera tripod and some slide film to experiment with. I read all I could about this apparition. I decided that if I took one hundred shots of Halley I might get at least one respectable picture to pass on to my four kids.

My tools for this noble quest? An old Mamiya-Sekor camera, the thirty-year-old 3-inch reflector my dad gave me on my thirteenth Christmas, and the new binoculars my wife bought me that could be whacked out of focus by the slightest movement.

My practice sessions proved encouraging — until I proudly showed my slides to relatives, and they laughed at the pictures of tiny white dots. Secretly I vowed to show them.

By mid-winter I was ready. Halley was passing overhead near the Pleiades, totally unconcerned that I couldn't find it. Later that winter, when the comet was low on the western horizon, I finally did manage to pick out the little puffball. Considering where I live, this was no small feat. All lousy Cleveland jokes aside, this is the cloudiest area in the country and there's plenty of air and light pollution as well.

I traveled northeastern Ohio's backroads at night trying, mostly in vain, to find a dark site I could use to take pictures. I found a farmer's field and a fairly dark road skirting LaDue Reservoir, both thirty minutes from home.

By February my vigil had begun in earnest. Every morning at 3:30 a.m. I rolled out of bed to check for the ever-present blanket of thick clouds. If the clouds seemed likely to clear, I'd don my Eskimo clothes, load up the van, and fly off to the countryside like a knight in search of the Holy Grail. My first two trips were a waste, but on the third clear morning Halley's Comet at last showed itself, rising majestically over the lingering eastern cloud cover. I quickly snapped away before my cold camera (and body) froze up.

First I used my regular 55mm lens and then switched to my trusty 200mm telephoto. By dawn I gave up and headed home. Once I didn't realize I'd left my 55mm lens on the hood of the van until I was halfway home. I returned to the site and found it cracked and bent on the gravel road.

After an early morning rendezvous with the comet, I'd quickly change and fly off to teach my "eager, well-behaved, quiet, and mature," eighth graders some good old American history. What a day!

By my seventh trip to the country I'd concocted a wooden hand-cranked tracking device I'd seen in *Outdoor Photographer*. It was bulky and tedious to operate, but it did a fairly good job of locking my camera on target without giving me star trails. I bought a 3x tele-converter and coupled it to my 200mm lens on my tracking device. It was way too heavy and sensitive for my flimsy setup: if a duck sneezed across the reservoir, my lens shook and blurred the shot.

Another night I got my van stuck in a farm field, and an hour later the police stopped to see what criminal activity I was engaged in.

By April I had ventured out fifteen times, taken about 150 exposures, and spent about $100. The fruits of my labor? About one hundred shots of the comet: thirty were average, four or five were good, and one was outstanding. I blew the best one up to 11x14, matted and framed it, titled it "A Tell-Tale Tail," and entered it in the Cleveland Natural History Museum's Astrophotography contest in May.

All those solitary cold nights paid off: three weeks later I won first place. My photo is still a big hit. I've had numerous copies made for friends and students who, like me, wanted to see and own a little piece of history.

Richard F. Burns
Novelty, OH

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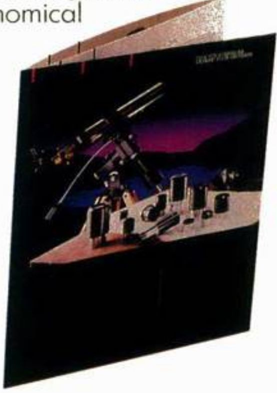

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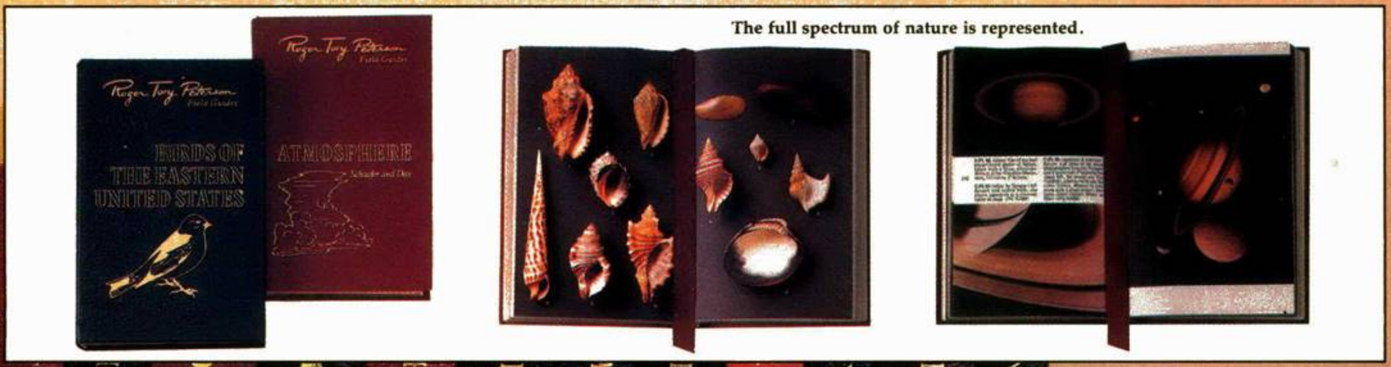
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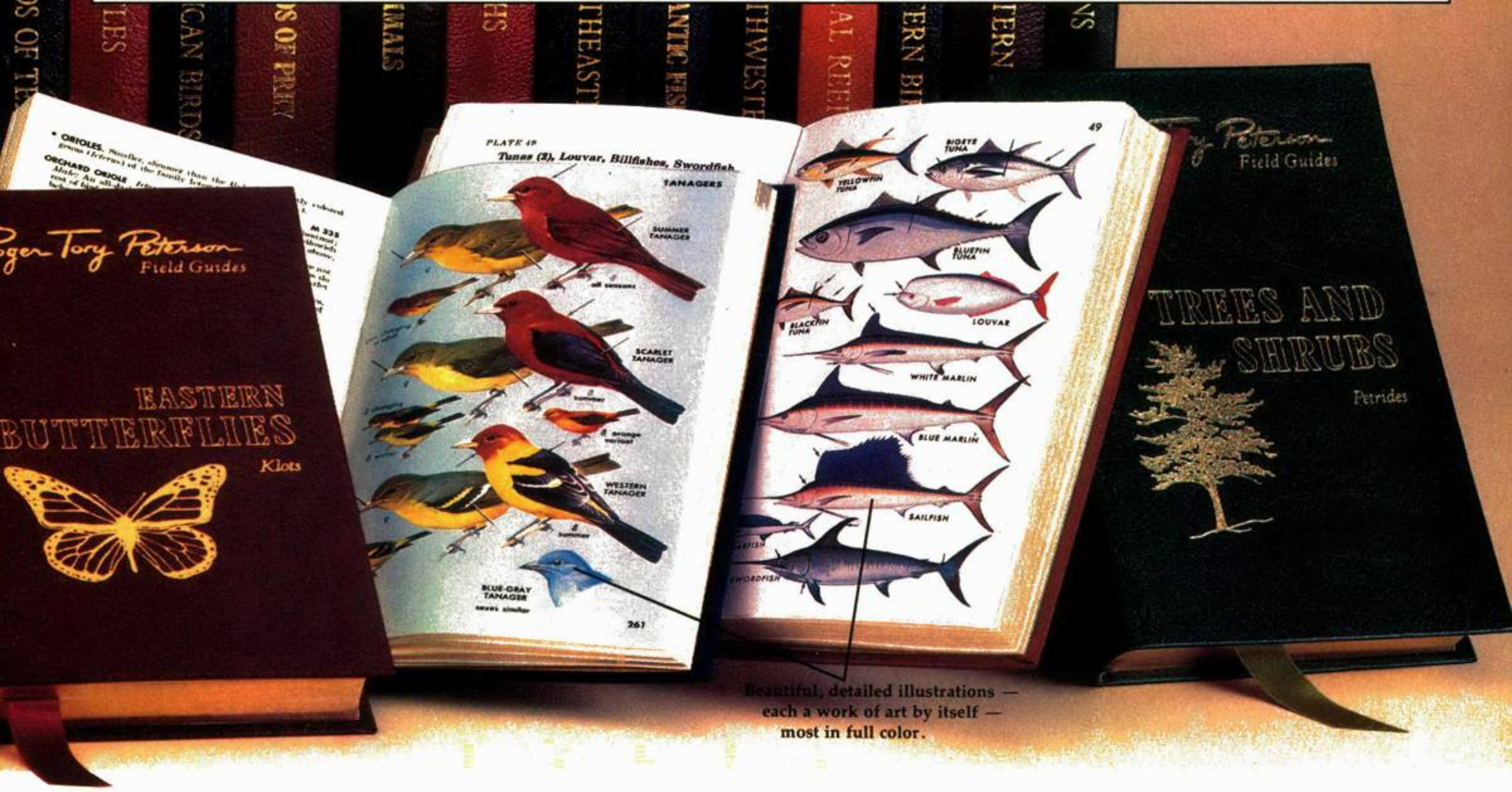
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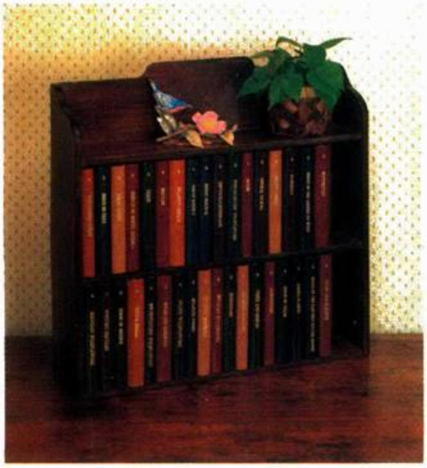

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ASTRONOMY
In Focus

Astronomy in Your Local Media

Sir / Michael S. Smith's adventures in "How to Teach (and Learn) Astronomy? Write a Column!" (Forum, February 1987) are delightful and instructional. I hope they'll inspire other amateur and professional astronomers to try the same thing. However, if you feel you lack writing talent, you may instead want to lobby your local media to add a regular astronomy feature. Astronomy columns do exist. Here are three:

"Exploring the Universe," a monthly column by the Astronomical Society of the Pacific, 1290 24th Avenue, San Francisco, CA 94122.

"Star Date," a short daily tape for broadcast media from McDonald Observatory, Deborah Byrd, University of Texas, Austin, TX 78712.

"Michigan Spacelog," my column, which is more irregular. Contact Wono Lee, University of Michigan, Information Services, 412 Maynard Street, Ann Arbor, MI 48109-1399.

Jim Loudon
University of Michigan Exhibit
Museum of Natural History
Ann Arbor, MI

Sir / I appreciated "How to Teach (and Learn) Astronomy? Write a Column!" by Michael S. Smith. In an entertaining way he explained why amateurs should communicate through the press with the general reader about the delights and importance of astronomy. This communication should be regarded as an essential activity of the average astronomical society.

Because I write about astronomy in the north of England, I can confirm that the press is always eager for a regular supply of informed writing about astronomy. This is the best way to counteract or at least balance the proliferation of nonsense about the stars and space that frequently dominates sections of the press.

We have to demonstrate that the facts about astronomy are more interesting and exciting than the fantasies, that man hasn't conquered space yet and still has a long way to go, that all this concerns the man on the street, and that astronomy is not the private property of astronomers, amateur or professional.

Harold Gooch
Newcastle-upon-Tyne, England

Metaphysical Concerns

Sir / I am as much an amateur at philosophy as I am at astronomy, but I feel obliged to point out that the word metaphysics has a more proper meaning than the "common" one used by Tony Rothman and George Ellis in "Has Cosmology Become Metaphysical" (February 1987). The authors stated that since medieval times "metaphysics has always connoted something that transcends physics." This is false.

Metaphysics is the branch of philosophy that asks the question "Where are we?", whereas epistemology asks "How do we know it?" *Webster's Unabridged Dictionary* defines metaphysics as "the branch of philosophy that deals with first principles and seeks to explain the nature of being or reality (ontology) and of the origin and structure of the world (cosmology)." Cosmology is part of metaphysics, not different from it.

James M. Badura
Hayward, CA

Sir / "Has Cosmology Become Metaphysical?" was interesting and informative. The authors are correct in stating that "after Immanuel Kant metaphysics took on its common meaning: the study of questions that cannot be proved or disproved by scientific experiments." Claiming there is a level or aspect of reality not subject to reason, Kant's philosophy was a systematic attack on the mind of man.

Metaphysics deals with the nature of existence itself; Kant's philosophy divorced this study from observation and reason. If there are aspects of cosmology that are presently unknown, filling in these gaps with educated guesses — like the inflation model — is proper, as long as the guesses are based closely on what is known and are clearly identified as guesses. If further relevant evidence turns up, the guess can advance to a more tenable theory. Or it can be discarded, as the steady state theory was.

A book review in the same issue demonstrates that ideas have consequences. Robert Burnham's review of "In Advance of the Landing: Folk Concepts of Outer Space" (Astronomy Reviews) gives an example of people who staunchly believe there are questions that cannot be proved or disproved by scientific experiments (or reason). Like Mr. Burnham I found this book depressing. He said it well in his last comment: "But, after a generation of real space travel, it's depressing that the cosmic confederacies inside these people's minds glow brighter than what's really out there."

Immanuel Kant's philosophy helped bring those people to that state.

Rodney Schroeter
Random Lake, WI

Astronomy in Both Hemispheres

Sir / Observational and scientific astronomy should be a supranational concern, and ASTRONOMY is to be commended for bringing up-to-date coverage to a world audience.

But, since your readers are predominantly from the United States, it is understandable that much of the material is directed toward them. Sometimes, though, it is presented in such a way that someone outside U.S. borders, even in neighboring Canada, might think the sky belongs to Americans.

An example of this occurs in "Mercury in the Evening Sky" by Robert Burnham (Eye in the Sky, February 1987) when Eridanus is decribed as being "far below the southern horizon." Whose horizon?

Fr. Lucian J. Kemble, O.F.M.
Cochrane, Alberta, Canada

— All ASTRONOMY readers south of the equator receive our special Southern Hemisphere edition with a sky map and observing information. For those readers we don't hesitate to point out, for example, that Hercules just rises above the northern horizon in August. Our planet is round — and ASTRONOMY recognizes that fact.

The Challenge of the Helix Nebula

Sir / In "A Delightful Dozen of Planetary Nebulae" by Charles M. Juhnke (Gazer's Gazette, October 1986) the author comments that NGC-7293 "is a challenge in 6-inch and 8-inch telescopes." I have read similar comments in various books and magazines.

I find these remarks difficult to understand because my friends and I use NGC-7293's naked-eye visibility as a guide to sky transparency while observing Aquarid meteor streams. Only on very poor nights is the nebula not visible.

M. L. Clark
Langford, West Australia

— The Helix Nebula, NGC-7293, has a total magnitude of 6.5, which means that technically it is just visible to the naked eye under a very dark sky. However, because it has an exceedingly low surface brightness, the Helix is difficult to see in telescopes with small fields of view. This is especially true for northern observers who see the object only a few degrees above the horizon.

How Long Is Longitude?

Sir / Has the Earth shrunk? In "What Time Is It?" by Richard C. Walter (Equipment Atlas, February 1987) a degree of longitude equals approximately fifty miles.

My calculations, based on a circumference of 25,000 miles and the usual 360 degrees in a circle, yield a figure of 69.444 miles per degree, which means an arcminute is equal to 1.1574 miles. I know the Earth is a little flatter at the poles, but I don't think it's hamburger-shaped.

Andrew Dale
Geneva, Switzerland

— The length of a degree of longitude is approximately 24,892 miles divided by 360, multiplied by the cosine of the latitude. At a latitude of 45 degrees, this is 49 miles, and it increases to 58 at 30° north latitude. This range includes most of Europe and the United States.

How Exotic Is Daedalus?

Sir / The plan for the Daedalus starship in "Star Trek" by David Darling (Stellar Frontiers, March and April 1987) is nothing but a pipe dream inspired by science fiction. The concept seems to be nothing more than a foolish expenditure of precious resources. Why not promote what you promote best — observing?

By the time Daedalus reaches Barnard's star (at the end of the twenty-first century, by the reckoning in your article), telescope technology may well have made all the instruments aboard the spacecraft obsolete.

The power of telescopes might be increased hundreds, even thousands of times within the next century. To increase the velocity of spacecraft by such factors, however, would require Star Trek-type magic.

With a telescope one thousand times better than today's best, we might be able to make all kinds of interesting observations. The Daedalus project, on the other hand, would be a single, risky shot in the dark.

So, more on telescopes and observing and less on science fiction.

Peter Wilson
Phoenix, AZ

Sir / At the end of the first part of "Star Trek," David Darling promised "exotic methods of propulsion" in part two. Instead he gave us a repeat of the same old descriptions of nuclear pulse drives, nuclear fusion *a la* Project Daedalus, the Bussard interstellar ramjet, and the standard speculation about black holes as intergalactic transit stations.

ASTRONOMY readers deserve better and far more exotic ideas! So here are a few: maser- and laser-pushed lightsails; Starwisp, a microwave-pushed sail; and quark drives. These ideas are speculative but grounded in real-universe physics.

Joel Davis
Olympia, WA

Behind the Scenes

A World of Astronomy

What an exciting month this has been! Every day fresh reports of Supernova Shelton 1987A poured in from around the world. Our phone bill to Australia alone will be (pardon the cliche, but there's no avoiding it) astronomical. ASTRONOMY's Rich Talcott has been running the desk at "Supernova Central," and he has been very busy. This month's Stellar Frontiers features Rich's first report on this significant event.

I want to thank all of the enthusiastic Southern Hemisphere observers who've sent us observations and photographs. Within days of the supernova the first pictures arrived, and they've been arriving ever since. You don't know how important your enthusiasm and diligence have been in helping us put together our story on this major event, something most of us envious northern types are doomed to miss entirely. G'day — and thanks!

For our North American contingent of readers we offer our "1987 Summer Travel Guide," chock full of astronomical places to see and things to do during the summer months. Kris Majdacic has been working for months to plan and assemble this 26-page special section. It's the first time we've done a guide like this — and we're sure you'll like it. Summer offers the best weather for enjoying the hobby, and you'll be surprised at how many things there are to see and do for the astronomy enthusiast.

And if we didn't list your club, star party, or special summer event in this year's Summer Guide, please let us know about it. We'll update our mailing list and you can be sure we'll include you in next year's Guide.

Our feature article this month reports on how astronomers have made raw spacecraft data understandable. Those of you in Europe and the United Kingdom should continue to be proud of your countries' pivotal role in the Giotto and Vega missions to Comet Halley. Although the public furor has died down, astronomers are still very excited about comets, and the results they're getting are fantastic.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

From prepublication reviews—

> *"The book is full of truly scientific substance and does not shy away from leading its reader to complex and serious questions of cosmology . . . Few popular science books more strongly radiate the excitement of, and the love for, the search into the origin of our universe, and therefore of ourselves."*
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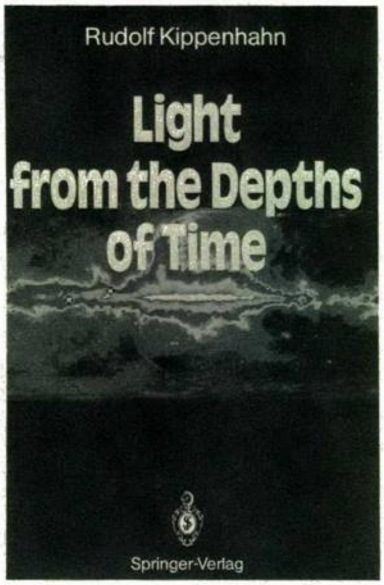
> **Peter Meyer**
> Professor of Physics
> University of Chicago

From the author of the bestselling 100 Billion Suns . . .

Rudolf Kippenhahn

LIGHT FROM THE DEPTHS OF TIME



Come along on an exciting search for answers to the ultimate questions about the universe. Your guide to the structure and history of the cosmos is Rudolf Kippenhahn, whose knowledge and skill in explaining that knowledge to laymen is perhaps without parallel. **Light from the Depths of Time** spans the breadth of cosmology, the most exhilarating and rapidly developing field of science. It complements and expands upon **100 Billion Suns'** coverage of stellar evolution.

Without recourse to mathematics, Kippenhahn makes the difficult concepts of cosmology accessible to anyone with an interest in the stars. By clever use of a two-dimensional 'flatland' and the space-voyaging dreams of a hypothetical everyman, he portrays the universe as currently accepted by today's astrophysicists and explains the essentials required for an appreciation of the latest cosmological speculations. **Light from the Depths of Time** is a timely new way to begin or continue your cosmological education.

Contents: Introduction. Anatomy of the Milky Way. Light. Speeding Up the Milky Way. Plumbing the Depths of the Milky Way. The Island Universe Debate. The Universe is Expanding. The Big Bang in Flatland. Expansion and Gravity. The Realm of the Nebulae. The Radio Sky. The Mysterious Quasars. . . . and There Was Light. The Intelligent Universe. Appendices. Author and Subject Index.

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ASTRONOMY
Reviews

Norton's Star Atlas, 17th edition
Arthur P. Norton
116 pages + 16 maps, cloth, $29.95
John Wiley & Sons (1986)

More than three-quarters of a century after its birth, doughty *Norton's* is still soldiering on. When the first edition appeared in London bookshops, George V had just become king of England and William Howard Taft was president of the United States. The solar system ended at Neptune, "spiral nebulae" were thought to be relatively nearby solar systems in formation, and astrophysics was a fledgling discipline still trying out its wings.

Norton's was designed to accompany two classic observing manuals: T. W. Webb's *Celestial Objects for Common Telescopes* and Admiral Smyth's *Cycle of Celestial Objects*. *Norton's* provided an atlas of the entire sky down to slightly beyond the naked-eye limit and plotted hundreds of nonstellar objects. If the atlas section was a great boon to backyard observers, so was the text. In the text you could find tables converting magnitudes to brightness differences, parallaxes to parsecs and light-years, temperatures (K) to temperatures (C) and (F), and so on. If you wanted to know decimal parts of day, you could look that up. If you needed to change R.A. hours and minutes to degrees, a table gave you the answer. For just about any useful little fact an amateur astronomer needed, this book provided a quick, handy answer.

If this sounds like a crazy hodgepodge, you're exactly right; and because it gathered all that useful information, dear old *Norton's* was treasured by everybody who owned a copy. If you had to make do with only one book on astronomy, *Norton's* was hard to beat. I bought my first copy in 1964 (a fifteenth edition), and since then it has accumulated layers of notes and scribblings in its margins. In my copy long-gone comets still course the stars along their faded pencil tracks. (In later years I also picked up a fourth edition from 1927 and the original 1978 printing of this seventeenth edition.) But as the decades rolled by, astronomy advanced apace. In 1973 several authors completely rewrote and reformatted the text material, which by then had become grossly outdated. They gathered most of the tables into one section, and their new text was a mixture of then-current astrophysical fact and backyard observational astronomy. In 1978 the seventeenth edition included more changes but, I regret to say, *Norton's* still comes across as something of a fossil.

The tone of the text might best be described as Brit-stalwart. The text assumes that backyard astronomers are mainly interested in doing serious, useful work. It is big on observation of solar system objects, telling you, for example, how to make transit timings of Jovian markings and how to monitor Mars for surface changes. (It also gives the formula for deriving the Zurich [Wolf] and Greenwich sunspot numbers and has little solar disk pictures showing the orientation of the Sun at various times of the year.) I found this section of the text to be the best and most useful. I wish, however, that the later section on variable stars was better balanced: much space and a few diagrams describe the different kinds of variables, but only two short paragraphs tell you how to observe them.

I suspect the section on telescopes provides an oblique portrait of what British amateurs were using a decade ago. You'll look in vain for mention of those large aperture Dobsonian light-buckets so popular today. Likewise, there is no mention of the ubiquitous Schmidt-Cassegrain scope. The description of mountings is woefully inadequate, and the authors have dropped the old how-to article on building your own telescope mounting. The advice about how to care for your telescope is generally good, although the method given for polar aligning an equatorial scope is more lengthy and time-consuming than, say, the star-drift method.

The section on astrophotography will disappoint beginners. You get no more than a brief look at a few essentials and, moreover, its recommendations of film and photographic optics are badly out of date (at least for North American readers). The section doesn't even discuss piggyback astrophotography. Hypersensitizing? Never heard of it. Astronomical emulsions on 35mm film stock? Same thing. Nor is this section terribly informative about equipment: guidescopes, it says, should have focal lengths "as great as possible and certainly not less than ten times the focal length of the photographic system." I feel sorry for any astrophotographic neophyte who encounters that as his only introduction to guidescopes. I think omitting a complex subject is better than covering it in such a sketchy way.

The Moon is shown in an 11-inch-diameter map that depicts major craters and landforms. The map is printed in tones of blue-gray that go "gray" under red light, and the accompanying text surveys the kinds of lunar formations you can see. Unfortunately, this section reads as if it were written sometime in the 1950s and reflects only marginally what has been learned in the years since.

The star charts are plotted in epoch 1950.0, no longer the epoch of choice since epoch 2000.0 has pretty well swept the field. They feature an old-fashioned convention for depicting star brightnesses using one-magnitude increments. A relatively standard symbol is now used for nonstellar objects, but just one type of symbol is used to represent all types of deep-sky objects.

More inconveniences: the objects are labeled with the antiquated Herschel numbers. While a conversion table is provided in the text of the book, flipping back and forth is tiresome just to learn that "object so-and-so" is really NGC-7662. (On the charts at least M-objects are given their proper numbers and tiny superscript Ms.) I also find the use of Roman numerals for labeling hours of right ascension very irritating, because you always have to stop and interpret them to locate the right piece of sky.

The lists of recommended objects,

printed on the back of each chart, are strongly weighted toward double stars and variables. The "Nebulae and Clusters" category (which is meant to include galaxies as well) usually gets short shrift; even the list for the rich Coma-Virgo region mentions almost nothing but Messier objects. In Scorpius and Sagittarius the list once more runs thin and again is mainly comprised of M-objects. This may or may not be a drawback, depending on what you want to look at, but it doesn't reflect what most people wish to observe today.

The Milky Way is depicted in my 1964 and 1978 editions with a smooth light-green tint that in no way interferes, under white light or red, with the objects plotted under it. In this reprint of the 1978 edition, however, the tint is heavier and colored blue. You can read the objects and labels well enough under white light, but under red light the blue drops to a dark "gray" that all but obliterates whatever is plotted beneath it.

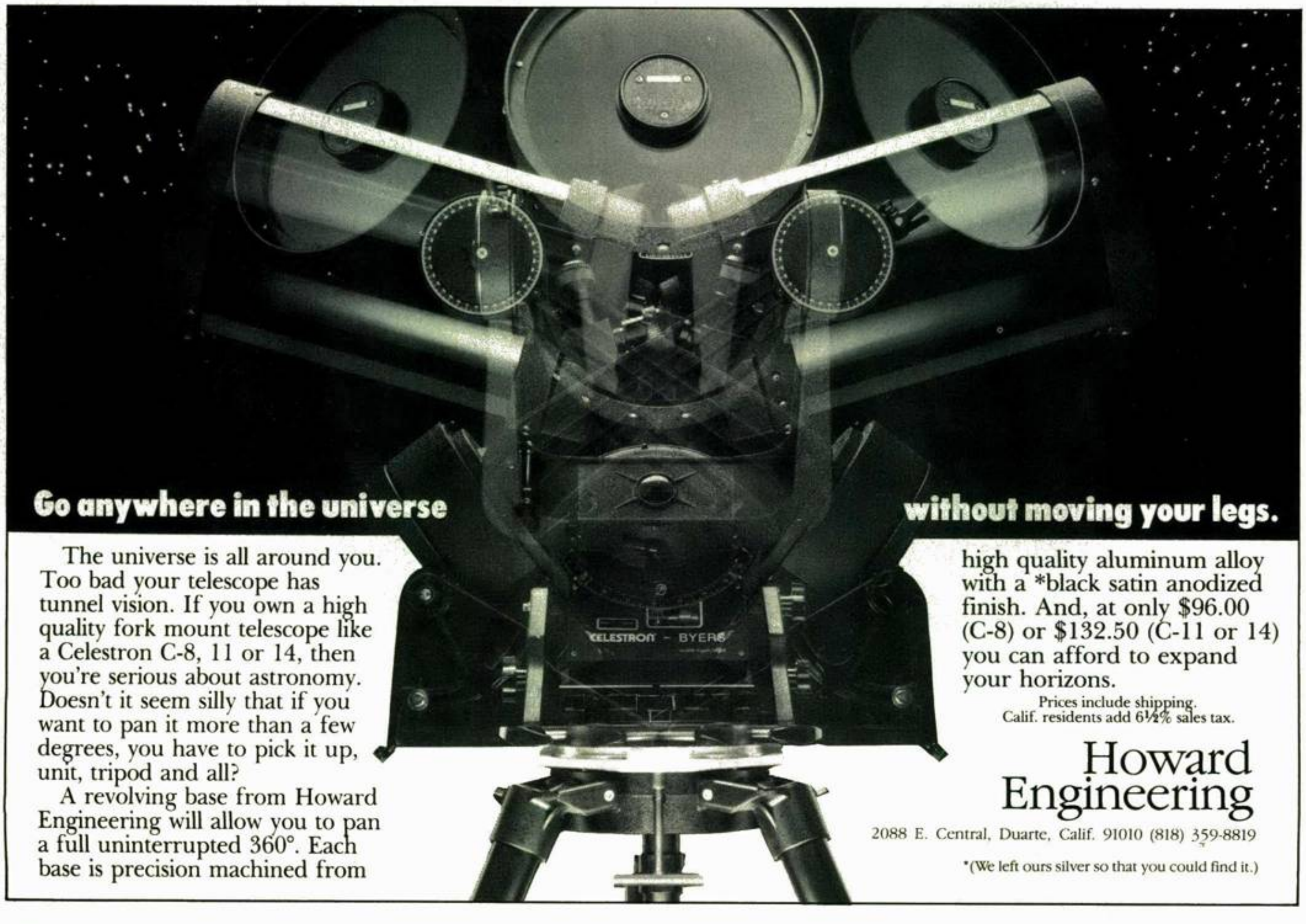
Lastly, to use an appropriate Anglicism, *bad cess* to the bean counter who cheaped-out and decreed the star charts should be printed on the same weight of paper as the rest of the book and bound in like every other page. The older editions, including my 1978 seventeenth edition, had one-piece charts printed on slightly heavier stock bound into the atlas on stubs of paper, which allowed them to open completely flat. The result of the new method is that the celestial equator and all objects lying near it — such as Orion's belt stars and M-78 — slip down into the gutter between the two halves of the chart. You can find them all right, but only by bending back the spine of the book. Moreover, in my review copy the left- and right-hand chart pages do not always align across the gutter. (The binding is sewn, I admit, but that is little consolation.)

Well then, is this new version of *Norton's* worth your $30? After looking over the book carefully, I have to say no. For $15 or even $20 you could probably overlook its flaws. But for $30, you'd do much better to spend another $5 and get *Sky Atlas 2000.0*. Never mind that it doesn't have all the text material; you should get that stuff elsewhere in better and more up-to-date form. In the end it pays to look carefully at your observing needs and then chose specific works that suit them best. For example, if you want an introductory star atlas, try the splendid little book *The Night Sky* by Ian Ridpath with charts by Wil Tirion (it costs only $5) or perhaps the *Mag 6 Star Atlas* from Edmund Scientific ($17). For more advanced observers Tirion's *Sky Atlas 2000.0* ($35) is unsurpassed.

The biggest problem here is that, besides being a star atlas, *Norton's* tries to be a general astronomy textbook too. Therefore, its space is wasted with explanations about things like spectral classification, color index, absolute magnitude, the H-R diagram, spectroscopy — all topics that belong in a regular textbook. The same academic fussiness can be sensed in the sections that expound on observational astrophysics and cosmology. While these subjects are perennially fascinating, they really have little to do with what you can actually see in your backyard scope. Second, the material becomes dated incredibly fast. For instance, cosmologists today pay no attention whatever to the steady state model of the universe, though the text seems to rank it equal to the Big Bang. To stay on top of today's research, you should read the articles in ASTRONOMY for new results and look over an introductory textbook every few years to get a coherent summary.

The time has come to recognize that it's no longer necessary — or desirable — for one's star atlas be an all-in-one astronomy reference library. To the extent that amateurs can indeed make "serious observations," *Norton's* is not the appropriate place to learn how. Moreover, it falls down badly when it tries to cover areas that have grown too sophisticated for the "once over lightly" treatment.

I am sorry to say this, for *Norton's* did yeoman work in its day, but the time has come to turn it out to pasture.
Robert Burnham.



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*(We left ours silver so that you could find it.)

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Celestron 20x80 Deluxe binoculars $429
High magnification for astronomical viewing, plus 3.5° wide field. With sturdy slide balance tripod mount.

Celestron C-11 with Starbright $3295
11" 2800mm Schmidt-Cassegrain captures deep sky nebulae color with superior resolution, in a portable instrument. Limited quantities. C-11 wedge and tripod $895 with purchase of telescope.

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Illustration by David Csicsko

ASTRONOMY'S 1987 SUMMER TRAVEL GUIDE

It's summer! Time to head out on the open road to see new places. Time to look up at the sparkling sky on those warm summer nights. Whether you're spending the summer backpacking in a silent forest or jetting off to the excitement of the big city, there's always something for the astronomically minded traveler to see or do. Meteors, the Milky Way, and all-night star parties beckon after dark; the huge telescopes of professional observatories and the riches of space and science museums fill the day. This special, 26-page section of ASTRONOMY is your guide to a summer full of activities under both the stars and the Sun.

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Observatories, planetariums, and museums throughout the United States and Canada

EYE ON THE SKY 54

Celestial events in June, July, and August

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Astronomy clubs and star parties provide companionship for summer observing

SUMMER ASTROCALENDAR 68

FOCAL POINTS

Observatories, planetariums, and museums for astronomy enthusiasts to visit throughout the United States and Canada

ARIZONA

Barringer Meteor Crater

Barringer Meteor Crater, located in northern Arizona forty miles east of Flagstaff, is one of the youngest impact craters on Earth — 49,000 years old, according to a recent estimate. It is a member of a unique group of about one hundred craters formed by the impact of interplanetary debris.

Barringer is over three-quarters of a mile in diameter, over three miles in circumference, and 570 feet deep. When approached from the ground the crater is difficult to detect because the rim rises only one hundred to two hundred feet above the surrounding plain. From the air, however, the crater is easy to spot: not as a circular structure but as a square with rounded corners.

Because Barringer's terrain so closely resembles that of the Moon, NASA designated the crater as the training site for U.S. astronauts going to the Moon.

You can get a close-up view of the crater either by walking the rugged 3-1/2-mile rim trail or by peering from numerous observation decks overhanging the crater. You can also learn about the crater's origins at Meteor Crater's Museum of Astrogeology, which features exhibits that vividly portray the meteor's impact and the resulting devastation. You can even touch a 1,406-pound meteorite, the largest found in the area. A lecture on meteor crater history is given throughout the day. *Patricia L. Barnes.*

ALABAMA

Huntsville

Marshall Space Flight Center. 35812. (205) 544-0034.
Bus tours feature displays of Space Shuttle components, the historic test site of the Redstone Rocket that carried astronauts Alan Shepard and Gus Grissom into space, the neutral buoyancy simulator, which closely duplicates the weightlessness of space, and Spacelab and Skylab displays. *Tours arranged by the Alabama Space and Rocket Center, 1-800-633-7280; nominal fee.*

ALASKA

Fairbanks

Geophysical Institute. University of Alaska-Fairbanks. Elvey Building, 99775. (907) 474-7598.
Tours of aerial and Landsat laboratories, slide shows. Rand McNally globe (eight feet in diameter). Displays of atmospheric and auroral phenomena photographed from Earth and Spacelab III. *Open 8 a.m.-5 p.m.; tours Thursday 2 p.m.*

ARIZONA

Flagstaff

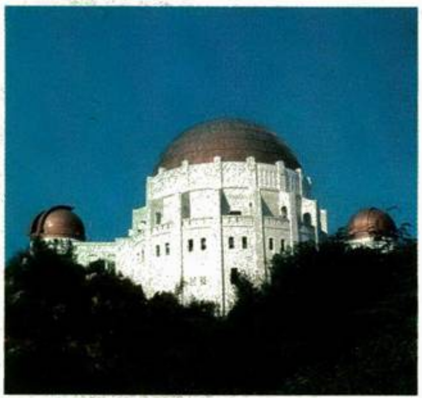
Barringer Meteor Crater. Forty miles east of Flagstaff. Meteor Crater Enterprises, 121 East Birch, 86001. (602) 774-8350.
Impact crater. 3-1/2 mile rim trail, observation decks. Museum of Astrogeology with exhibits, lectures, movies. Astronaut Hall of Fame, 1,406-pound meteorite. (See profile above.) *Open May 15-September 15 6 a.m.-6 p.m.; admission fee.*

Lowell Observatory. 1400 West Mars Hill Road, 86001. Mary Lou Evans, (602) 774-2096.
Tours, slide shows, and lectures on observatory history and current research. Historic 24-inch Clark telescope, visitors' center. Evening slide presentation and telescope viewing. *Visitors' center open 10 a.m.-4:30 p.m.; tours Monday-Saturday 10 a.m. and 1:30 p.m.; open Friday (June-August) 8-10 p.m., slide presentation and viewing on the half hour.*

Northern Arizona University Campus Observatory. Department of Physics and Astronomy, 86011. Andrew P. Odell, (602) 523-2661.
Tours. All-night viewing sessions July 24-25. Open house Thursday 7:30-10 p.m.

Tucson

Grace H. Flandrau Planetarium. University of Arizona, 85721. Michael E. Bakich, (602) 621-4556.
Planetarium program: "Eyes on the Universe" Tuesday 7:30 p.m., seasonal programs. Science displays, artwork, 16-inch public telescope, educational programs. *Theater open daily except Monday, adults $1; seasonal program Wednesday-Saturday 7:30 p.m., Saturday-Sunday 1:30, 2:30, and 3:30 p.m.; adults $3.50.*



Griffith Observatory, Los Angeles, California

Kitt Peak National Observatory. Box 26732, 85726-6732. (602) 325-9204.
Fifteen major operating telescopes, three visitor's galleries, visitors' center, films, guided tours. (See profile on page 43.) *Visitors' center open daily 10 a.m.-4 p.m.*

Steward Observatory. University of Arizona, 85721. (602) 621-2288.
Public observatory evenings, monthly seasonal sky programs, telescope viewing.

CALIFORNIA

Berkeley

Lawrence Hall of Science. University of California, 94720. Jill Kangas, (415) 642-5362.
Planetarium programs, star games exhibit offers hands-on experience with telescopes, children's astronomy classes.

Edwards

Ames Research Center. Hugh L. Dryden Flight Research Facility, 93523. (805) 258-3446.
Tours, movie: "From X-1 to the Space Shuttle." *Reservations required; programs Monday-Friday 10 a.m. and 1 p.m.*

Fresno

Discovery Center. 1944 North Winery Avenue, 93703. Jeanne Larson, (209) 251-5533.
Star parties (July and August) Friday dusk to 10 p.m. *Adults $1.*

Los Angeles

Griffith Observatory. 2800 East Observatory Road, 90041. Dr. E. C. Krupp, (213) 664-1181.
Planetarium show: "Space, Time and Black Holes." Foucault pendulum, solar telescope, six-foot Earth and Moon globes, meteorites, Giant Tesla Coil, Cosmic Ray Cloud Chamber, lasarium. *Open daily 12:30-10 p.m., Saturday 11:30 a.m.-10 p.m.; planetarium shows Monday-Friday 1:30, 3, and 8 p.m., Saturday-Sunday 1:30, 3, 4, and 8 p.m.; adults $2.75.*

Barringer Meteor Crater, Flagstaff, Arizona

ARIZONA

Kitt Peak National Observatory

If you're in the vicinity of Tucson, Arizona, you owe yourself a visit to Kitt Peak—"your" observatory. Funded by your tax dollars, the observatory bristles with fifteen major operating instruments.

Kitt Peak is primarily a research institution, but it is readily accessible to visitors. A visit to the observatory allows you a rare close-up view of the world of modern astronomy.

You can examine the McMath and Mayall telescopes firsthand in glass-enclosed visitor galleries. These galleries, combined with the visitors' center, comprise a self-directed tour of the observatory. Paths are well-marked and, if you look closely, you'll see many of the high desert plants that cover the mountain top identified with small signs. The 2.1-meter reflector also has a glass-enclosed gallery for visitors.

The large visitors' center concentrates on astronomical education. A heliostat beams an image of the Sun into the center whenever weather permits. A short walk away is the McMath solar telescope, rising like an iceberg at a diagonal, its huge shaft disappearing underground three hundred feet below you.

Films are shown twice daily and 45-minute guided tours of the McMath and the 2.1-meter telescopes are also available. *Tom Wilson.*

Mount Hamilton

Lick Observatory. 95140. Joseph Calmes, (408) 429-2771.
Visitors' gallery for 120-inch telescope, photo displays, exhibits, working seismograph, model of 10-meter telescope to be built in Hawaii. Public telescope viewing, talks, displays Friday evenings July 10-September 11; request tickets in advance by writing. *Visitors' gallery open daily 10 a.m.-5 p.m.; main building open daily 1-5 p.m.*

Emilie Burnham

Palomar Mountain

Palomar Observatory. 92060.
Self-guided tours, telescopes, museum, videos. *Open daily 9 a.m.-4:30 p.m.*

Pasadena

Jet Propulsion Lab. 4800 Oak Grove, 91109. (818) 354-7006.
Tours by appointment. Public tours twice monthly. Open House June 6-7 and June 13-14.

Rohnert Park

Sonoma State University. Department of Physics and Astronomy, 94928. Dr. Joseph S. Tenn, (707) 664-2594.
Monthly public viewing nights June 5, July 31, and August 28. *9-11 p.m.*

San Diego

Mount Laguna Observatory. Department of Astronomy, San Diego State University, 92182. Burt Nelson, (619) 265-6175.
Astronomical museum featuring historical and modern astronomy with interactive exhibits, public lectures, telescope viewing.

Reuben H. Fleet Space Theater. P.O. Box 33303, 92103. (619) 238-1168.
Planetarium program: "We Are Born of Stars" (June-August). Science center. *Shows daily; adults $4.75; science center open daily 9:45 a.m.-10:30 p.m.; adults $1.50.*

San Francisco

Exploratorium. Palace of Fine Arts, 3601 Lyon Street 94123. Linda Dackman, (415) 563-7337.
Museum of science and natural phenomena, satellite simulator. *From July 4 open Wednesday 11 a.m.-9:30 p.m., Thursday-Friday 11 a.m.-5 p.m., Saturday-Sunday 10 a.m.-5 p.m.; adults $4.*

COLORADO

Boulder

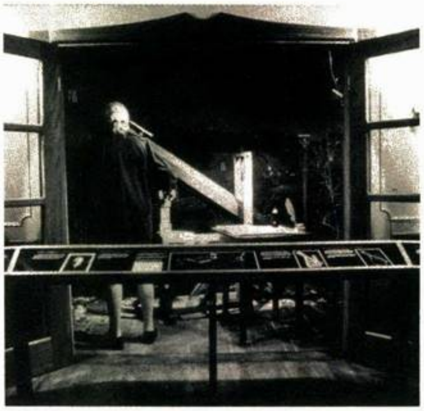
Fiske Planetarium and Science Center. Regent Drive, University of Colorado, 80309. Julie Reahard, (303) 492-5002.
Public starshows and startalks, free telescope viewing, hands-on science displays. Laser shows June 6, 9:30 and 11 p.m.; July 4, 10:30 p.m. and 12 a.m. Daytime matinee: "Space Primer Star Show" Wednesday at 10 a.m. Boulder evening skies talks Thursday 8 p.m. *Open 7:30 a.m.-4:30 p.m., Thursday and Friday evenings 8 a.m.-9:30 p.m.; adults $2; closed June 6-19 (days) and August 17-24.*

Colorado Springs

USAF Academy Planetarium. 50 ATS/DOP, 80840-5566. Mickey D. Schmidt, (303) 472-2779.
Planetarium programs: "Spacebound" and "Visit to a Far Planet." *Programs May 24-August 16 daily except Monday, 12:30, 1:30, 2:30 p.m.*

Denver

Gates Planetarium. Denver Museum of Natural History. City Park, 80205. (808) 370-6374.
Planetarium programs: "Night Light" and "Colorado Skies" followed by star party first Sunday of month 7 p.m. Laser shows. (See profile on page 44). *Planetarium shows Monday-Sunday 12, 1, and 3 p.m.; Wednesday, Friday, and Saturday 7 p.m., adults $3; laser shows Monday-Sunday 2 and 4 p.m., Wednesday-Sunday 8 p.m., Friday and Saturday 9:15 and 10:30 p.m.; adults $4 (day), $5 (evening), combination planetarium and museum $5.25.*



Adler Planetarium, Chicago, Illinois

CONNECTICUT

Danbury

College Observatory. Western Connecticut State University, 181 White Street, 06810. Dr. Phillip K. Lu, (203) 797-4218.
Weekly planetarium show, weekly open house. *All summer activities by request.*

New Britain

Copernican Space Science Center. Central Connecticut State University, 1615 Stanley Street, 06050. Dr. David Menke, (203) 827-7419 or (203) 827-7852.
Planetarium shows: "End of the World" (June),

"Epic of Gilganesh" (July), "Giants of the Solar System" (August-September). Meteor shower observing session August 11. Public observatory open Friday-Saturday 8-10 p.m.; public star parties. *Planetarium shows Friday-Saturday at 8:30 p.m.; adults $1.50.*

West Hartford

Science Museum of Connecticut/Gengras Planetarium. 950 Trout Brook Drive, 06119. Fran Downey, (203) 236-2961.
Programs: "Skylights" for youngsters Monday-Saturday 11:30 a.m., Sunday 2:30 p.m.; "Death of the Dinosaur" Monday-Saturday 12:30, 1:30, 2:30, and 3:30 p.m., Sunday 1:30 and 3:30 p.m. *Museum open Monday-Saturday 10 a.m.-5 p.m., Sunday 1-5 p.m.; adults $3.50 (museum and planetarium).*

DELAWARE

Greenville

Mount Cuba Astronomical Observatory. P.O. Box 3915, Hillside Mill Road, 19807. Grace A. Quirk, (302) 654-6407.
Sponsors Skylab Camp; public night programs with slide presentation, tour of facilities, planetarium session, and telescope viewing. *Reservations required.*

DISTRICT OF COLUMBIA

National Air and Space Museum. 6th Street and Independence Avenue S.W., 20560. (202) 357-1400.
Twenty-six galleries, Samuel P. Langley IMAX theater, Albert Einstein Planetarium. (See profile on page 46.) *IMAX and planetarium shows daily, adult tickets for each $2; museum tours 10:15 a.m. and 1 p.m. daily; open daily 10 a.m.-5:30 p.m.*

U.S. Naval Observatory. 34th and Massachusetts Avenue, N.W., 20392. Public Affairs Office, (301) 653-1543.
Telescope viewing on tour nights, displays in main building, astronomers on hand to answer questions. *Open Monday (except federal holidays) 8:30 p.m., first come basis; request group reservations for up to 35 persons in advance in writing; tour not suitable for young children; walking up hills and stairs required.*

COLORADO

Gates Planetarium

Delightfully cool summer nights lend themselves to an evening's stargazing in Colorado, especially when you start off with a visit to Denver's Gates Planetarium. This facility, located in Denver's City Park, is a showpiece of the Denver Museum of Natural History.

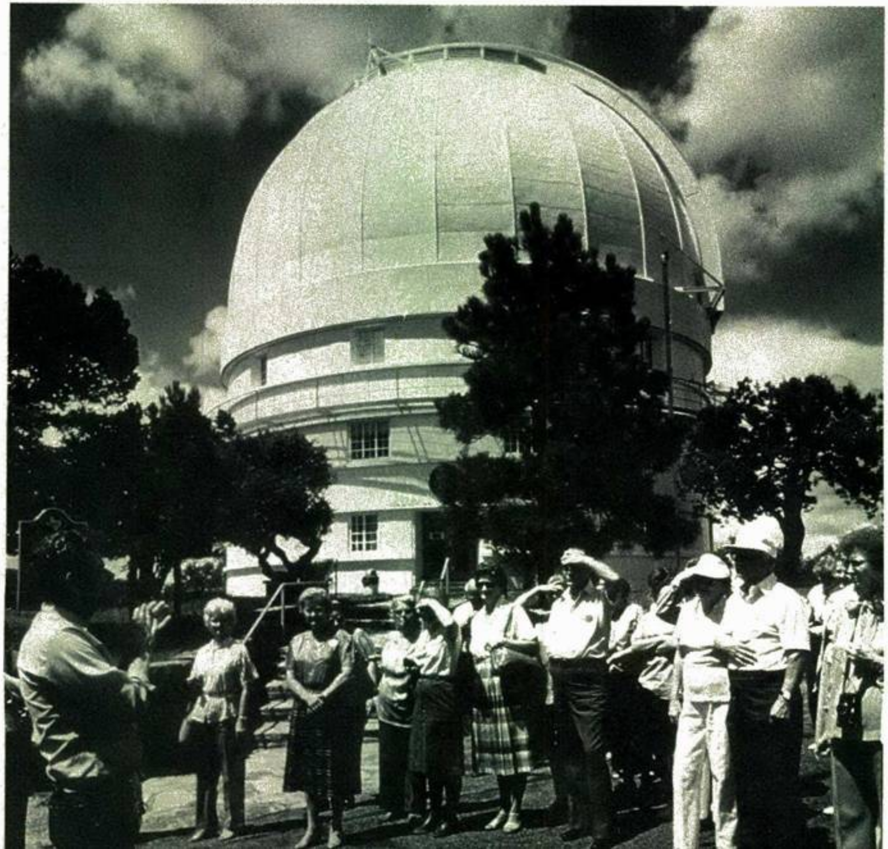
Gates offers a wide variety of programming for astronomers of all levels and tastes. The current public planetarium show, "Nightlife," investigates the myths and mysteries of the Moon and includes a look at the night sky over Denver from dusk to dawn.

Once a month "Colorado Skies," a look at the stars, planets, constellations, and celestial events visible in the night sky, is presented. During the summer the staff holds monthly public star parties and makes telescopes available on the west terrace of the museum after the program. Gates also offers a full slate of laser shows.

The Star Theater was extensively renovated in 1982 to bring state-of-the-art planetarium programming to Denver audiences. Included in the upgrade were a Minolta planetarium projector, special effects projectors, and a custom-designed sound system.

The Denver Museum of Natural History features natural history exhibits, wildlife dioramas, and big-screen films in the Phipps IMAX Theater. *Carolyn Collins Petersen.*

McDonald Observatory, Fort Davis, Texas



FLORIDA

Bradenton

Bishop Planetarium. 201 10th Street West, 33505. John Hare, (813) 746-4132.
Daily planetarium shows, observatory open evenings of first and third full weekends of month. *Planetarium shows Tuesday-Sunday 1:30 and 3 p.m.; Friday-Saturday 7:30 p.m.; observatory open 8:30-9:30 p.m.*

Cocoa

Astronaut Memorial Hall and the BCC Planetarium. 1519 Clearlake Road, 32926. Mike Hutton, (305) 631-563.
Planetarium programs: "The Weather Machine," Friday 3 and 7 p.m. Astronaut Memorial Hall (NASA related exhibits and Hall of Astronauts) open weekdays 8 a.m.-12 p.m. Open house at observatory first and third Fridays of month, 7-10 p.m. *Adults $2; no admission fee for Memorial Hall.*

Daytona Beach

Museum of Arts and Sciences Planetarium. 1040 Museum Boulevard, 32014. Lee Golden, (904) 255-0285.
Weekend star shows, laser light shows. *Star shows Friday 7 p.m., Saturday 3 p.m., adults $2; light shows Friday 8 and 9 p.m., Saturday 8, 9, and 10 p.m., adults $3.*

Jacksonville

Alexander Brest Planetarium. Jacksonville Museum of Arts and Sciences, 1025 Gulf Life Drive, 32207. Frank Smith, (904) 396-7062 or (904) 398-STAR (recording).
Multimedia productions on subjects ranging from space travel to star myths, quasars and black holes to UFO's, historical astronomy to science fiction. Star shows: "The Universe Game" (June 6-September 6); Cosmic Concerts; "Sky over Jacksonville," free weekly show followed by telescope viewing Sunday 9 p.m. *Museum open Monday-Wednesday 9 a.m.-5 p.m., Thursday-Friday 10 a.m.-8 p.m., Saturday 11 a.m.-8 p.m., Sunday 1-5 p.m., adults $2; star show Monday-Saturday at 12, 2, and 4 p.m. (included with admission to museum), Friday-Sunday 8 p.m., adults $2, ($1 with purchase of Cosmic Concert ticket); Cosmic Concert Friday and Saturday 9, 10, 11 p.m., adults $3; Classical Cosmic Concerts Saturday and Sunday 7 p.m.*

Kennedy Space Center

Spaceport, USA. Kennedy Space Center, 32899. (305) 452-2121.
Rocket Garden exhibit, bus tours of Kennedy Space Center and Cape Canaveral, IMAX film: "The Dream is Alive," multimedia presentations, displays, space art gallery in Galaxy Center. *Open daily 9 a.m.-dark, tours continuously between 9:45 a.m. and two hours before dark; IMAX film, adults $2.75.*

Orlando

John Young Planetarium. 810 East Rollins Street, 32803. Mike Murray, (305) 896-7151.
Planetarium feature shows, sky shows, observatory skywatch Friday 9 p.m. *Open Monday-Thursday 9 a.m.-5 p.m., Friday 9 a.m.-9 p.m., Saturday 12-9 p.m., Sunday 12-5 p.m.; feature star shows Monday-Sunday; Sky Shows Friday-Sunday; adults $3.*

Tallahassee

Florida State University Planetarium. Richards Undergraduate Physics Laboratory Building, Atomic Drive, 32306. Dr. Vasken Hagopian, (904) 644-3734.
Occasional planetarium shows; call ahead.

West Palm Beach

South Florida Science Museum and Planetarium. 4801 Dreher Trail North, 33405. Gary M. Bogner, (305) 832-1988.
Planetarium shows daily, Gibson Observatory. *Shows daily 3 p.m., Friday 7 p.m., Saturday-Sunday 1 p.m., adults $1; observatory open Friday dark until 10 p.m.*

GEORGIA

Atlanta

Fernbank Science Center. 156 Heaton Park Drive, N.E., 30307. Mary Hiers, (404) 378-4311.
Planetarium show: "In the Depths of Space" (June 2-September 4), children's summer matinee (June 16-August 30). Observatory open house. Apollo 6 capsule, space suit exhibit, meteorite exhibit, Georgia tektite exhibit, astronomy film and lecture series. *Planetarium shows Tuesday-Friday 8 p.m., Saturday 11 a.m., Wednesday, Friday, Saturday, Sunday 3 p.m.; children under five not admitted to the planetarium programs, under twelve must be accompanied by an adult, adults $2; children's matinee Tuesday-Friday 11 a.m. and 1 p.m., Saturday-Sunday 1:30 p.m.; observatory Thursday and Friday 8 p.m. -10:30 p.m., 8-9:30 p.m., if cloudy; closed if weather inclement; exhibit hall open Monday 8:30 a.m.-5 p.m., Tuesday-Friday 8:30 a.m.-10 p.m., Saturday 10 a.m.-5 p.m., Sunday 1-5 p.m.*

Rock Spring

Walker County Science Center/Planetarium. P.O. Box 10, Highway 95, 30739. Wayne Robinson, (404) 764-1111. Information line (404) 638-STAR.
Planetarium programs by appointment only, telescope viewing after evening programs. *Open 8 a.m.-4 p.m.; evening program 7 p.m.; adults $1.*

Savannah

Savannah Science Museum Planetarium. 4405 Paulsen Street, 31405. Laura Lawton, (912) 355-6705.
Planetarium shows Saturday-Sunday 3 p.m., June topic "Summer Constellations," displays. *Adults $1.50.*

Young Harris

Rollins Planetarium. Young Harris College, 30582. James R. Westlake, Jr., (404) 379-3990. Free planetarium programs followed by telescopic observing. *Shows Friday 8:30 p.m. (July-August).*

HAWAII

Hilo

Mauna Kea Observatory. 177 Makaala Street, 96720. (808) 935-3371.
Tours Friday-Monday, free public programs and displays at Onizuka Center for International Astronomy at Hale Pohaku (9,200 feet altitude), telescope viewing on Saturday evening summit tour. (See profile on page 48.) *Reservations required for Saturday evening tour; four-wheel drive vehicles required for transportation above Hale Pohaku; extremely thin air and potential for temperatures near freezing or below.*

New England Science Center, Norton Observatory, Worcester, Massachusetts

ILLINOIS

Chicago

Adler Planetarium. 1300 South Lake Shore Drive, 60605. Martha Benaroya, (312) 322-0337.
Sky show: "Intruders from Outer Space;" children's shows: "Sky Eye" (April-July 25), "Magic Sky" (August 1-November). Three floors of exhibits on astronomy and space exploration, a world-renowned collection of early scientific instruments. Doan Observatory open Friday nights as part of the evening sky show. *Open daily 9:30 a.m.-4:30 p.m. until June 16, Fridays until 9 p.m., June 16-August 31 9:30 a.m.-5 p.m., Fridays until 9 p.m.; shows daily, adults $2.50; children under six not admitted; children's shows Saturday 10 a.m.; adults $1.*

Dekalb

Northern Illinois University.. 60115. Physics Department Observatory, (815) 753-1772. *Call for appointment.*

Evanston

Northwestern University. 2145 Sheridan Road, 60201. Melville P. Ulmer, (312) 491-5633. Dearborn Observatory open house, tours Friday 9 and 10 p.m., reservations required; Lindheimer Astronomical Research Center open house Saturday 2-4 p.m., no reservations needed.

Normal

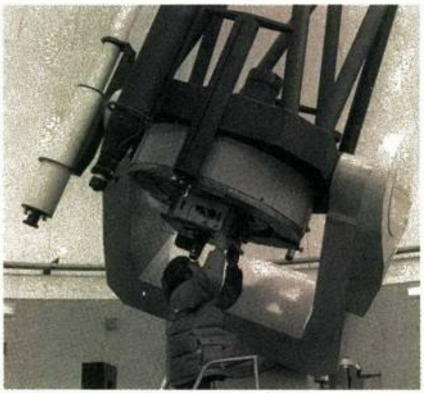
Physics Department Planetarium. Corner of College Avenue and School Street, Illinois State University, 61761-6901. Carl J. Wenning, (309) 438-2496.
Planetarium show: "North Star to Southern Cross" Monday and Wednesday (June 15-July 29) 8:15 p.m.; planetarium and post-program sky viewing. *Pre-schoolers not admitted.*

River Grove

Cernan Earth and Space Center. Triton College, 2000 5th Avenue, 60171. Bart Benjamin, (312) 456-5815.
Planetarium and multimedia programs, laser light shows, Space Hall with exhibits on space exploration and astronomy, telescope viewing. *Planetarium programs Tuesday-Friday 7:30 p.m., Saturday 2, 3, and 7:30 p.m., Sunday 2 and 3 p.m., adults $3; laser light show Tuesday-Thursday 9 p.m., Friday-Saturday 9 and 10 p.m., and Sunday 4 p.m., adults $4.*

Rockford

Time Museum. 7801 East State Street, 61125. Dorothy Mastricola, (815) 398-6000 extension 2943.



Fernbank Science Center, Atlanta, Georgia

Museum exhibits illustrate historical development of time-keeping devices: sundials, waterclocks, sandglasses, calendar stones, astrolabes, astronomical clocks, watches, and devices. *Open Tuesday-Sunday 10 a.m.-5 p.m.; adults $3; Monday-Friday by appointment only; weekend tours.*

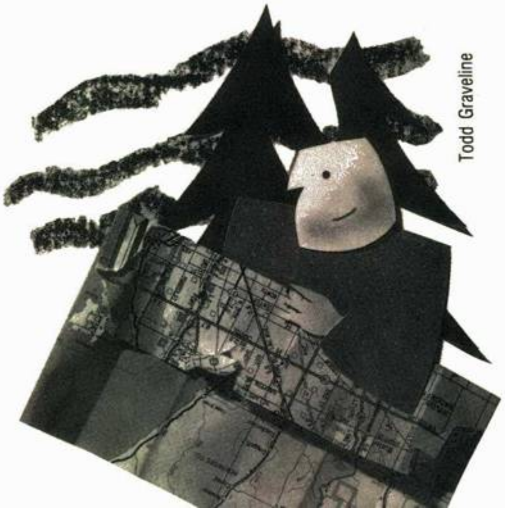
INDIANA

Evansville

Koch Science Center and Museum. Evansville Museum of Arts and Sciences, 411 S.E. Riverside Drive, 47713. Mitch Luman, (812) 425-2406.
Planetarium shows Tuesday, Thursday, Saturday, and Sunday 2 p.m. plus 3:30 p.m. Sunday. *Adults $1.*

Fort Wayne

Edwin Clark Schouweiler Planetarium. St. Francis College, 2701 Spring Street, 46808. R. G. Stoeckley, (219) 483-8068.
Planetarium show: "Those Incredible Black Holes," July 11-17 daily 2 and 8 p.m. *Adults $2.*



Todd Graveline

DISTRICT OF COLUMBIA

The National Air and Space Museum

Visitors to the National Air and Space Museum, one of the world's most popular museums, are treated to twenty-six galleries featuring astronomical, spacecraft, and aviation exhibits.

The "Stars" gallery provides an in-depth look at man's exploration of our Galaxy and beyond. The gallery highlights the study of astronomy from Stonehenge to the Space Telescope, covering the history of calendars and astrology based on star sightings, major astronomical developments since the seventeenth century, scientific instruments, and a look at the future of astronomical research. On display you'll find Skylab's Apollo Telescope Mount, the x-ray telescope Uhuru, and a full-scale engineering mock-up of the International Ultraviolet Explorer.

The "Exploring the Planets" gallery depicts the planets and what we know about our solar system. The displays feature the discovery of the planets, the latest views of each of our planetary neighbors, and a full-scale replica of a Voyager spacecraft. "Current" planetary weather reports are available in a taped telecast by Gordon Barnes, a Washington, D.C., weatherman.

Multimedia presentations are given in the Albert Einstein Planetarium and IMAX films such as "The Dream Is Alive" (about the Space Shuttle with footage filmed by astronauts in space) and "To Fly!" (about airplanes) are shown in the Samuel P. Langley Theater. *Patricia L. Barnes.*

Terre Haute

Indiana State University Observatory. 47809. Dr. Robert Howe, (812) 237-3294.
Observatory viewing June 1-July 2, July 6-August 4. Demonstrations of computer processing of astronomical images from ground-based and space-based observatories by appointment only. *Observatory open Tuesday and Friday 8-10 p.m.*

IOWA

Cherokee

Sanford Museum and Planetarium. 117 East Willow, 51012. (712) 225-3922.
Planetarium programs by appointment and on last Sunday of month at 2 p.m. Research library, astronomy classes.

Waterloo

Grout Museum of History and Science. 503 South Street, 50701. Alinda Campbell, (319) 234-6357.
Planetarium programs: "A Summer Night" (June 2-13), "The People" (June 16-30), "By Bonestell" (July 1-11), "On a Clear Night" (July 14-31), "Meteors" (August 1-15), "Doomed Dinosaurs" (August 18-September). Preschoolers planetarium programs June 6, July 11, and August 1 at 3 p.m. *Open Tuesday-Friday 10 a.m.-4:30 p.m., Saturday 1-4 p.m., closed July 4; shows daily at 2 p.m.; free passes given out at 1:45, first come basis; no children under five.*

KANSAS

Greensburg

Haviland Meteorite. The Big Well, 315 South Sycamore, 67054. Penny Keller, (316) 723-2261.
1,000-pound meteorite.

Hutchinson

Kansas Cosmosphere and Space Center. 1100 North Plum, 67501. (316) 662-2305.
Cosmosphere theater with OMNIMAX projector, Hall of Space, planetarium, future astronaut training program. (See profile on page 49.) *Cosmosphere shows daily, adults $4; planetarium shows Saturday-Sunday 2, 3, 4 p.m., adults $1.50; reservations suggested.*

Wichita

Wichita Omnisphere and Science Center. 220 South Main, 67202. Jose Olivarez, (316) 264-3174.
Planetarium shows: "Planet Probe" (June 6-July 26), "Star Quest" (August 1-30). Model of solar system, meteorite display, Mars display, celestial spheres, inner workings display of a reflector telescope, children's shows. *Shows Saturday-Sunday 2, 3, 4 p.m., Thursday at noon, adults $2.50; Hands-On Science Center open Tuesday-Friday 8 a.m.-5 p.m., Saturday-Sunday 1-5 p.m.*

National Air and Space Museum, District of Columbia

KENTUCKY

Louisville

Rauch Memorial Planetarium. University of Louisville, 40292. Thomas E. Boone, (502) 588-6664 (tape), (502) 588-6665.
Planetarium programs: "Islands in the Sky," weekend starlight rock shows, children's show in July. *Planetarium shows Wednesday and Friday 7 p.m., Sunday 2 and 4:30 p.m., adults $2; rock shows Friday and Saturday 8 and 9:15 p.m., adults $1.50; children shows Saturday 12:30 and 2 p.m., children $1; closed August.*

LOUISIANA

Lafayette

Lafayette Natural History Museum and Planetarium. 637 Girard Park Drive, 70503. Donna Savoie (318) 261-8350.
"Discover Science," interactive exhibit, late June-August. Planetarium programs Monday, Tuesday, and Sunday. Telescope nights Tuesday 8:45 p.m. Space Week programs July 16-24. *Museum open Monday, Wednesday, Friday 9 a.m.-5 p.m., Tuesday and Thursday 9 a.m.-9 p.m., Saturday and Sunday 1-5 p.m.*

PROTOTYPES

Kansas Cosmosphere and Science Center, Hutchinson, Kansas

New Orleans

Martin Marietta/Michoud Assembly Facility. 13800 Old Gentilly Road, 70129. (504) 255-2479.
Group tours, reservations required.

MAINE

Easton

Francis M. Malcolm Science Center Planetarium. Box 186, U.S. Route 1-A, 04740. John T. Meader, (207) 488-5451.
Planetarium programs Friday at 6:30 p.m. until June 12 and after August 21, telescope viewing afterward, exhibits. *Open Monday-Friday 8 a.m.-4 p.m., adults $2; closed June 15-August 15.*

Orono

University of Maine Planetarium and Observatory. Wingate Hall, 04469. Alan Davenport, (207) 581-1341.

Planetarium program: "The Dawn of Astronomy" (July 10-31) Friday 7 p.m., observatory open after programs. *Adults $3 (planetarium only).*

Portland

Southworth Planetarium. University of Southern Maine, 96 Falmouth Street, 04103. Roy A. Gallant, (207) 780-4249.
Planetarium shows, solar system exhibit prepared by the National Geographic Society.

MARYLAND

Baltimore

Davis Planetarium. Maryland Academy of Science, 601 Light Street, 21218. (301) 685-5225.
Planetarium show: "Light for All," exhibits and demonstrations, IMAX theater. *Open Monday-Friday 10 a.m.-5 p.m., Saturday 10 a.m.-7 p.m., Sunday 12-7 p.m.; science center $5, planetarium $1; children under four not admitted to planetarium.*

Greenbelt

Goddard Space Flight Center. 20771. (310) 286-8981.
Self-guided walking tours, Delta rocket, Mercury, Gemini, and Apollo models, Moon rock, weather station, satellite telephone, Amsat Satellite facility; model rocket launch on first and third Sundays of the month, 1 p.m. *Open Wednesday-Sunday 10 a.m.-4 p.m.; reservations for groups of twenty or more.*

Kitt Peak National Observatory, Tucson, Arizona
Photo by Von Del Chamberlain

MASSACHUSETTS

Boston

Boston University Astronomy Department. 725 Commonwealth Avenue, 02215. David Bradford, (617) 353-4884.
Open night observing Wednesday, stellarium/slide show or movie if cloudy. *Call (617) 353-2630 after 5 p.m. Wednesday about open night.*

Charles Hayden Planetarium. Science Park, 02114. (617) 723-2500.
Planetarium programs, exhibits. *Open Monday-Sunday 9 a.m.-5 p.m., Friday 9 a.m.-9 p.m.; adults (museum) $5, (theater) $5, (planetarium) $3, (museum and theater) $7.50; children under four not admitted to planetarium or theater; shows Tuesday-Sunday.*

Springfield

Springfield Science Museum. 236 State Street, 01103. Sara J. Orr, (413) 733-1194.
Oldest American-built planetarium projector in operation, observatory, planetarium program: "The Universe Game." *Open Tuesday-Sunday 12-5 p.m.; programs Tuesday and Thursday 3:30 p.m. (2:30 p.m. July/August), Saturday and Sunday 1, 2, and 3 p.m.; adults $1; children under six not admitted to planetarium.*

Williamstown

Milham Planetarium and Hopkins Observatory. Williams College, 01267. Jay M. Pasachoff, (413) 597-2188.
Hopkins Observatory celebrating 150th anniversary with exhibits of equipment from 1834 and displays of current space research, planetarium shows. *Shows Tuesday and Thursday 8 p.m., call for reservations.*

Worcester

New England Science Center. 222 Harrington Way, 01604. Jean Ingraham, (617) 791-9211 extension 42.
Eight-foot models of Milky Way and solar system, video theater, astronomical displays, Goddard rocketry exhibit, Alden Omnisphere (planetarium), Norton Observatory, classes, star parties. *Open Monday-Saturday 10 a.m.-5 p.m., Sunday 12-5 p.m., closed holidays; adults $3.50, no additional charge for planetarium; Norton Observatory open for solar viewing Saturday-Sunday 1-3 p.m.*

MICHIGAN

Alpena

Jesse Besser Museum/Sky Theater. 491 Johnson Street, 49707. Matt Linke, (517) 356-2202.
Planetarium program: "Death of the Dinosaurs" (June 14-August 2). *Museum open Monday-Friday 9 a.m.-5 p.m., Thursday 7-9 p.m., Saturday-Sunday 1-5 p.m.; programs Sunday 2 and 4 p.m., Thursday 7:30 p.m. in July and August; planetarium, adults $1.25; preschoolers not admitted.*

Ann Arbor

Ruthven Planetarium Theatre. Natural Science Museums, University of Michigan, 1109 Geddes Avenue, 48109-1079. Garry F. Beckstrom, (313) 764-0478.
Family astronomy programs, displays, exhibits, monthly astronomy film/lecture series, visitor nights with lectures, films, telescope viewing. *Family shows, adults $1.25; feature shows Saturday and Sunday afternoons, adults $1.50, children under five not admitted.*

East Lansing

Abrams Planetarium. Michigan State University, 48824. David Batch, (517) 355-4676.
Sky theater, blacklight gallery of astronomical artwork, 6-foot Earth globe, Apollo spacesuit, Geochron timepiece, Michigan meteorites, 6-inch Alvan Clark telescope. Planetarium show: "Adventures along the Spectrum" (through July 31). *Exhibit hall open weekdays 8:30 a.m. to noon, 1-4 p.m.; shows Friday and Saturday 8 p.m., Sunday 4 p.m., adults $2.50; closed August.*

Grand Rapids

Roger B. Chafee Planetarium of the Grand Rapids Public Museum. 233 Washington, S.E., 49503. David L. DeBruyn, (616) 456-3985.
Planetarium shows Wednesday-Sunday (June 14-August 30), children's sky show: "Camping with Grandpa" Wednesday-Friday, music and light show Wednesday-Saturday (July 8-August 29). Hall of the Universe. *Sky shows Thursday-Saturday 8 p.m., Wednesday-Sunday 2:30 p.m.; children's show Wednesday-Friday 1:30 p.m., adults $2; music show Thursday-Saturday 8 and 9 p.m.; adults $3; pre-schoolers admitted only to children's show.*

Marquette

Shiras Planetarium. Marquette Senior High School, 1203 West Fair Avenue, 49855. D. Scott Stobbelaar, (906) 225-4204.
Jupiter, Saturn, Uranus, Mars displays; Moon landing, Comet Halley, Space Shuttle displays; planetarium shows. *Shows Monday and Wednesday 7:30 p.m.*

MINNESOTA

Duluth

Marshall Alworth Planetarium. University of Minnesota-Duluth, 55812. Glenn Langhorst, (218) 726-7129.
Astronomy displays, original paintings of space and astronomical subjects by Jerry Bielicki, free planetarium shows. *Show Wednesday 7 p.m.*

Minneapolis

Minneapolis Planetarium. 300 Nicollet Mall, 55401-1992. Rodney M. Nerdahl, (612) 372-6644.

Emilie Burnham

Planetarium programs: "Land of the Southern Cross" (through June 14) Thursday 7:30 p.m., Saturday-Sunday 2 p.m.; "Starlit Nights" (June 20-September 6) Monday-Friday 11 a.m. and 2 p.m., Thursday 7:30 p.m., Saturday-Sunday 2 p.m. Space Week '87 (July 16-24), events space-related exhibits. *Adults $2.50.*

St. Cloud

Observatory and Planetarium. St. Cloud State University, 56301. David Targan, (612) 255-2013.

Camp Uraniborg astronomy camp for teenagers, teacher workshops, "Elderhostel" program for retired people, observatory/planetarium open house. *Irregular hours.*

St. Paul

The Science Museum of Minnesota. 30 East 10th Street, 55101. Becky Kirkpatrick, (612) 221-9480.

OMNIMAX film "Seasons" opens June 19. *Shows daily 11 a.m.-8 p.m.; information line (612) 221-9400.*

MISSISSIPPI

Jackson

Russell Davis Planetarium/Ronald McNair Space Theater. 201 East Pascagoula Street, 39201. Mary Herron, (601) 960-1550.

Planetarium shows, educational programs, exhibits. Cinema-360 films: "Another Day," "Beautiful Nevada," "The Space Shuttle: An American Dream," "Sentimental Journey: The Iron Horse Remembered." *Shows Tuesday-Friday 12, 2, 4, and 8 p.m., Saturday 2, 4, 8 p.m., Sunday 2 and 4 p.m.; adults $3.*

MISSOURI

Kansas City

Kansas City Museum. 3218 Gladstone Boulevard, 64123. Susan Peterson, (816) 483-8300.

Planetarium shows: "Death of the Dinosaurs" Tuesday-Sunday 1 p.m., also Saturday 11 a.m.; "Voyage of Discovery: Saturn & Uranus," Tuesday-Sunday 2:15 p.m., also Saturday and Sunday 3:30 p.m. *Adults $3; children under six not admitted.*

St. Louis

St. Louis Science Center. 5050 Oakland Avenue, 63110. (314) 289-4400.

McDonnell Star Theater, Space Week activities, monthly summer star parties, exhibits. (See profile on page 50.) *Open Monday-Thursday 9:30 a.m.-5 p.m.; Friday and Saturday 9:30 a.m.-8 p.m., Sunday 11 a.m.-5 p.m.; planetarium shows daily; no children under five; children's show Saturday 11 a.m. and "Night Sky Show" Saturday-Sunday 2 p.m., no age restriction; daily sessions in Computer Connection (fee), Discovery Room (fee) and Science Showplace (free); star shows, adults $3; "Night Sky" and children's shows, adults $2.*

NEBRASKA

Lincoln

Ralph Mueller Planetarium. University of Nebraska State Museum of Natural Science, 210 Morrill Hall, 68588-0338. Jack Dunn, (402) 472-2610.

Planetarium shows, laser light shows, Apollo Command Module. *Planetarium shows Tuesday-Friday 2:30 p.m., Saturday-Sunday 2:30 and 3:45 p.m.*

NEVADA

Las Vegas

Planetarium. Clark County Community College, 3200 East Cheyenne Avenue, 89030. Dale Etheridge, (702) 643-6060 extension 308.

Planetarium shows: "Solar System Spectacular" (through July 18), "Futurescape" (from July 22). Cinema 360 films: "The Magic Egg" (through July 18), "Space Shuttle: An American Adventure" (from July 22). Telescope viewing after last performance. Call (702) 644-5059 for show schedules and local astronomical information. *Shows Wednesday-Saturday 3:30, 6:30, and 8 p.m.; adults $3.*

Reno

Fleischmann Planetarium. University of Nevada, 89557. A. W. Johnson, (702) 784-4812.

Planetarium shows: "Land of the Southern Cross" plus dome movie, "Great Barrier Reef." Free telescope viewing Wednesday and Friday 9:15-10:15 p.m. *Shows daily 11 a.m., 1, 3, 7:30, and 9:15 p.m.; adults $3.50; children under six not admitted to evening shows.*

NEW HAMPSHIRE

Hanover

Dartmouth College. 03755. Thomas Kenyon, (603) 646-2034.

Shattuck Observatory public viewing Tuesday and Thursday 8-10 p.m.; museum.

HAWAII

Mauna Kea Observatory

Hawaii attracts many tourists each year, but few know about a unique astronomical attraction — Mauna Kea Observatory on the Big Island.

Currently in operation at the observatory, perched atop the 13,796-foot summit of Mauna Kea, are the University of Hawaii's 88-inch optical/infrared instrument, NASA's 120-inch optical/infrared telescope, the Canada-France-Hawaii Corporation's 144-inch optical/infrared telescope, and the 150-inch United Kingdom Infrared Telescope. The California Institute of Technology's new 34-foot submillimeter radio telescope rounds out the complex of major observatories. There are also two 24-inch optical telescopes on the summit.

Summit tours, featuring walks through the observatories to see the high-tech instruments, are conducted several times during the week. On Saturday evenings the summit tour includes telescope viewing through one of the 24-inch instruments.

Four-wheel drive vehicles are required for the trip on the saddle road to the summit because you will be traveling on very rough terrain. At the summit the air is extremely thin and temperatures can be near freezing or below.

When you visit Mauna Kea, be sure to take in the Onizuka Center for International Astronomy at Hale Pohaku at an altitude of 9,200 feet on the slopes of Mauna Kea. Weekly slide-lecture programs on astronomy and telescope-viewing programs are conducted at the visitors' center, which is at the scientists' residence complex. *John Penisten.*

NEW JERSEY

Toms River

Robert J. Novins Planetarium. Ocean County College, 08754-2001. Erik Zimmerman, (201) 255-4000.

Planetarium shows, children's shows. Until June 7: "Other Lands, Other Skies" Thursday-Saturday 8 p.m., Saturday 2 p.m.; "A Sky for All Seasons" Saturday-Sunday 3:15 p.m.; Young Children's Show (under six) Saturday 1 p.m. July 8-September 4: "Whirlpools of Suns" Tuesday-Friday 2 p.m., Thursday-Friday 8 p.m.; Young Children's Show Friday 3 p.m. *Closed June 8-July 6 and Saturdays and Sundays during the summer.*

NEW MEXICO

Socorro

National Radio Astronomy Observatory/Very Large Array Radio Telescope. P.O. Box O, 87801-0387. D. L. Swann, (505) 772-4011.

Maryland Science Center, Davis Planetarium, Baltimore, Maryland

Emilie Burnham

The VLA, the world's most powerful radio telescope, consists of twenty-seven identical 82-foot reflector antennas arranged along three radial arms, forming a Y-shaped array. Two of the arms are 13 miles long, and the third stretches 11.8 miles across the Plains of San Augustin. Free self-guided tours, radio astronomy, exhibits, slide show. *Visitor center open daily 8:30 a.m. until dusk.*

NEW YORK

Fredonia

Planetarium. SUNY College at Fredonia, 14063. Dr. Daniel C. Dobey, (716) 673-3370.

Ithaca

Spacecraft Planetary Imaging Facility. 317 Space Sciences Building, Cornell University, 14850. Margaret Dermott, (607) 255-3833.

Facility contains all the images returned from the U.S. unmanned space program from the earliest Ranger pictures of the Moon to the most recent pictures of Uranus from Voyager 2, readily accessible for browsing. Globes, models, video disc display system. *Open Monday-Friday 9 a.m.-4:30 p.m.; reservations required.*

Middle Island

Longwood District Planetarium. Longwood Middle School, Yaphank Road, 11953. Joe Caprioggio, (516) 345-2741.

Planetarium show: "Exploring Summer Skies" (through June 17).

New York City

American Museum of Natural History-Hayden Planetarium. 81st and Central Park West, 10024. (212) 873-1300.
Star shows, classes, concerts, laser shows, exhibits. (See profile on page 51.) *Planetarium shows daily, adults $3.75; laser shows Friday and Saturday 7:30, 9, and 10:30 p.m., adults $6.*

Rochester

Strasenburgh Planetarium. Rochester Museum and Science Center, 657 East Avenue, 14607. Charlene Oukes, (716) 271-4320 extension 411.

Schenectady

Schenectady Museum and Planetarium. Nott Terrace Heights, 12308. Susan C. French, (518) 382-7890
Planetarium shows, guided tours, classes, amateur radio station, and lecture series. Museum exhibits. *Open Tuesday-Friday 10 a.m.-4:30 p.m., Saturday-Sunday 12 to 5 p.m., closed major holidays; planetarium shows Saturday-Sunday 2:30 and 3:30 p.m., children's show Sunday 1:30 p.m.; adults $1.50 (museum), $2.50 (museum/planetarium).*

Syracuse

Rotary Planetarium and Discovery Center. 321 South Clinton Street, 13292. Stephen Karon, (315) 425-9068.
"The Solstice Is Coming" activities (June 20). Planetarium show: "Summer Starwatch," solar energy demonstrations; children's planetarium show: "A Trip to the Moon" (June 6, 20; July 4, 18; August 1, 15). *Open Tuesday-Saturday 10 a.m.-5 p.m., Sunday 12-5 p.m.; adults $1.*

KANSAS

The Kansas Cosmosphere and Space Center

The Kansas Cosmosphere and Space Center (KCSC) in Hutchinson, Kansas, the Midwest's largest space museum, is also known as "Right Stuff Central."

The Hall of Space museum displays more than $150 million worth of space artifacts, including a large and comprehensive exhibit of space suits, a complete set of flight-ready spacecraft including Mercury, Gemini, and the Apollo Command Module, plus space food and Moon rocks. The museum also contains hands-on exhibits, like the Lunar Module cockpit, which lets you simulate a Moon landing, and the astronaut databank, which answers questions about astronauts.

The KCSC's OMNIMAX theater presents films such as "The Dream Is Alive" (about the Space Shuttle with footage shot by astronauts in space) on a 44-foot tilted projection dome, accompanied by a custom six-channel sound system that provides a remarkable sense of "being there."

In addition to the OMNIMAX theater, the KCSC houses a planetarium that features programs for visitors of all ages. Live lectures familiarize audiences with the current nighttime sky. *John R. Vacca.*

NORTH CAROLINA

Chapel Hill

Morehead Planetarium. University of North Carolina, East Franklin Street, 27514. (919) 962-1248.
Planetarium shows: "The Ultimate Force" (through June 15), "Galaxy" (June 16-August 31). "Cosmic Cat" for young stargazers Saturday at 11 a.m. "Sky Rambles," $2. "To Fly," $2. *Shows nightly 8 p.m., Saturday and Sunday 1, 3, and 8 p.m.; weekday shows 1 and 3 p.m. (June 17-September 7), adults $3.*

Greensboro

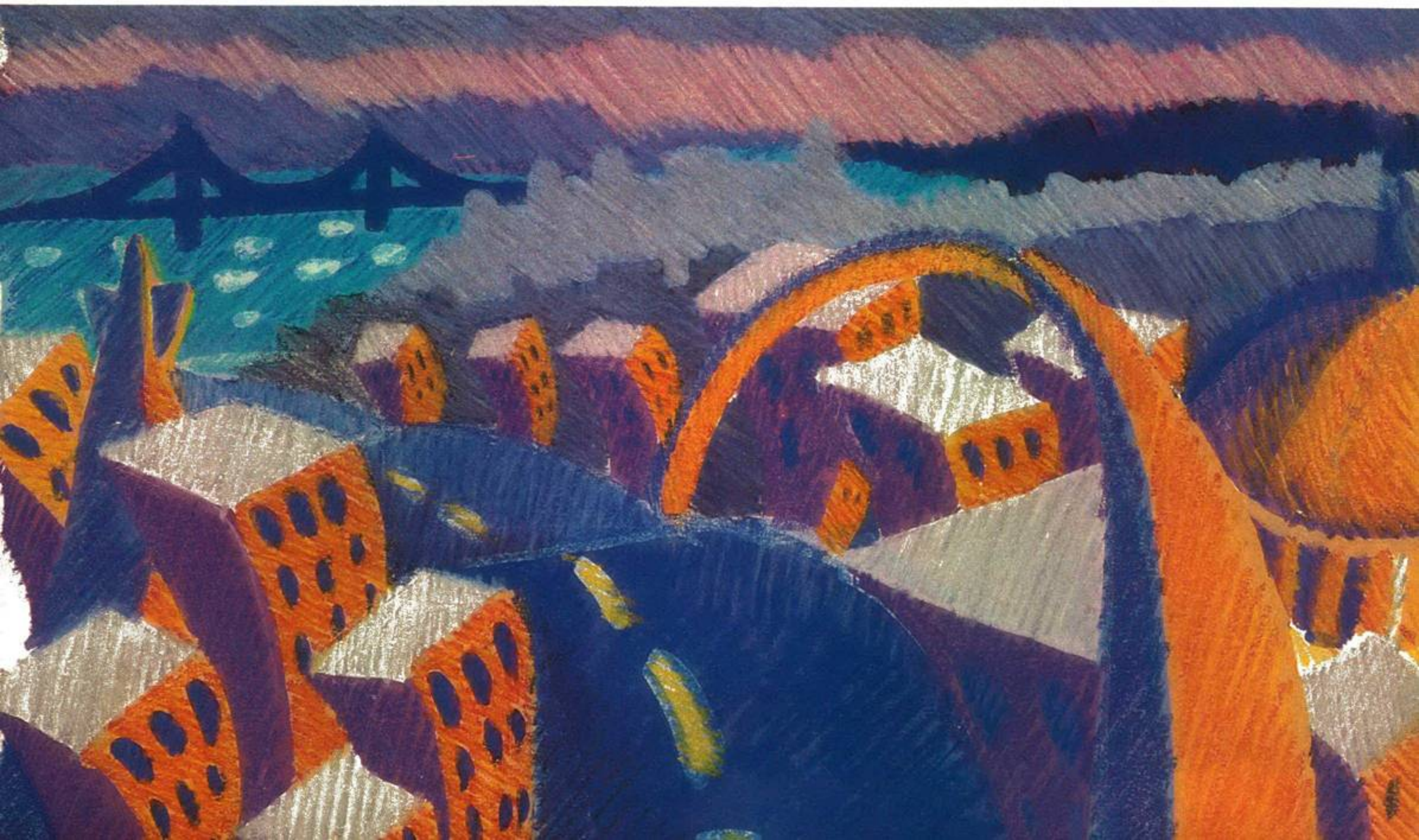
Edward R. Zane Planetarium. Natural Science Center of Greensboro, Inc., 4301 Lawndale Drive, 27408. Roger D. Joyner, (919) 288-3769.
Solar observatory with live and video recorded images of the Sun. Planetarium programs: "Starbound" (June 3-July 26), "Skywatchers of Ancient Mexico," (July 29-September). *Open daily 9 a.m.-4:45 p.m., Sunday 2-4:45 p.m.; shows Monday-Friday 11 a.m. and 12 p.m., Saturday 2 and 3 p.m., Sunday 2, 3, and 4 p.m.; adults $1; children under three not admitted.*

Three College Observatory. Department of Physics and Astronomy, University of North Carolina-Greensboro, 27412. Dr. Stephen Danford.
32-inch telescope open to the public. *Request reservations in writing.*

NORTH DAKOTA

Minot

State University of North Dakota-Minot. 58701. DeWayne Martin, (701) 857-3071.
University observatory. *Open house June 18 and 25, July 2 and 9, 10:30 p.m.-12:30 a.m.*



OHIO

Canton

Hoover Price Planetarium. McKinley Museum of History, Science, and Industry, 800 McKinley Monument Drive, NW, P.O. Box 483, 44701. Rosemary Anderson, (216) 455-7044.
Lunar lander model, Wally Schirra's space suit, solar system display, eclipse display, astronomy toy collection. Planetarium shows: "Voyager at Uranus" (June 1-26), "The Dinosaurs' Demise" (June 26-August 31). *Shows: Wednesday-Sunday afternoons, adults $3; children under five not admitted.*

Cincinnati

Cincinnati Museum of Natural History/Cincinnati Planetarium. 1720 Gilbert Avenue, 45202. Roberta Burnes, (513) 621-3889.
Computer-controlled laser video player showing selected astronomy subjects, history of space exploration exhibit, spacecraft models, future space settlement model. Planetarium shows: "The Missing Planet" (June 6-June 28), "Cosmic Questions" (July 5-August 31), Space Camp for eight-year-olds (July 27-31, August 10-14, call for registration fee). *Open Tuesday-Saturday 9 a.m.-5 p.m., Sunday 12:30-5 p.m., adults $2; planetarium shows daily, adults $1.50.*

University of Cincinnati Observatory. Physics Department, 45221-0011. Paul Nohr, (513) 321-5186.
"Astronomy Thursdays" include tour, lecture, and telescope viewing. *Advanced reservations required; not recommended for children under ten.*

Cleveland

Lewis Research Center. 21000 Brookpark Road, 44135. (216) 267-2001
Weekend programs: "NASA Aeronautics," "Focus on Lewis." June weekend movie: "Flight into Tomorrow" (June 6-7, 13-14, 20-21, and 27-28). Space, flight, applications of space research on Earth, terrestrial energy, materials research, propulsion, and Space Shuttle exhibits. *Open Monday-Friday 9 a.m.-4 p.m., Saturday 10 a.m.-3 p.m., Sunday 1-5 p.m.*

Mueller Planetarium. Cleveland Museum of Natural History, Wade Oval, University Circle, 44106. Joe DeRocher, (216) 231-4600 extension 237.
Special commemorative exhibit of Michelson-Morley experiment done at Case Western Reserve University one hundred years ago opens in August. Planetarium programs: "Fly By Night" (June), "Planetary Interiors" (July), "Ether/Or?" (August); young people's program. *Planetarium shows daily (June 22-August 31), Monday-Friday 2 p.m., Saturday-Sunday 2, 3, and 4 p.m.; young people's program Wednesday and Saturday 11 a.m.; adults $2.75 (museum), $.50 extra for monthly programs.*

Dayton

Dayton Museum of Natural History Planetarium and Apollo Observatory. 2629 Ridge Avenue, 45414. Arthur F. Goss, (513) 275-7431.
Planetarium shows: "Islands in the Sky" (June), "Bridges of Light" (July), "Trivia Galactica" (August). Free observatory public stargaze Friday dark-11 p.m., tours Tuesday 6-9 p.m., Perseid meteor watch. Astronomical displays concerning solar system and galactic astronomy, telescope mirror grinding and polishing facilities, junior observatory. *Shows Tuesday and Friday 7:30 p.m., Saturday 2:30 and 4 p.m., Sunday 2:30, 3:30, and 4:30 p.m.; children under six not admitted to shows; adults $2 (museum).*

Granville

Swasey Observatory. Denison University, 43023. Dr. Sandra B. Yorka, (614) 587-6477.
Usually open during the day, public nights.

Sylvania

Copernicus Planetarium. Lourdes College, 6832 Convent Boulevard, 43560-2898. Anthony G. Pisano, (419) 885-3211 extension 259.
Interactive displays on Earth's history, the history of life, fossils, meteorites, rocks, minerals. "The Extinction of Dinosaurs: How Delicate Is Life on Earth?" program (through August 31). *Open Monday-Friday 8 a.m.-4 p.m.*

Westerville

North American Astrophysical Observatory. Department of Physics and Astronomy, Otterbein College, 43081. Dr. Philip E. Barnhart, (614) 898-1516.
Tours of facility featuring 110-meter by 21-meter standing parabola radio antenna engaged in long-term survey and search missions, audio visual displays. *Tours and visits by appointment only.*

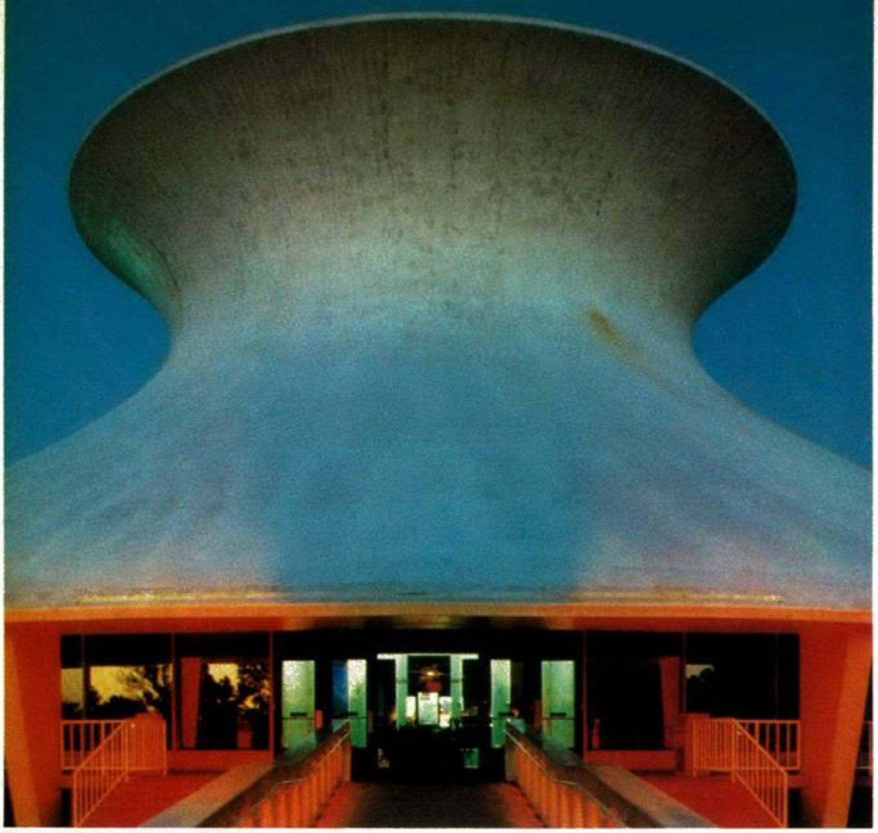
Youngstown

Youngstown State University Planetarium. 44555. Warren M. Young, (216) 742-3616.
Ward Beecher Planetarium shows Friday and Saturday. Mahoning Valley Observatory open house Wednesday (near Warren, Ohio).

OREGON

Bend

University of Oregon Pine Mountain Observatory. Bend-Burns Star Route, 97702. James C. Kemp, (503) 382-8331.
Pacific Northwest's only year-round research



St. Louis Science Center, St. Louis, Missouri

MISSOURI

St. Louis Science Center

Tucked into the southeast corner of St. Louis' Forest Park is the distinctive hyperboloid-shaped St. Louis Science Center (formerly the McDonnell Planetarium). The Science Center, operated under the aegis of the St. Louis Museum of Science and Natural History, has undergone $3 million in renovations and is the first phase of a project to establish a major midwestern science museum in St. Louis.

At the core of the building is the McDonnell Star Theater, which features one of four Digistar computer videographic planetarium projectors in the United States. The Star Theater's programming includes feature shows, seasonal night sky shows, and special programs for youngsters.

Monthly public star parties are planned for the summer, and the Star Theater staff is involved in planning for annual Space Week activities in July, which are set to coincide with a Festival of Flight celebration at the Science Center.

Surrounding the Star Theater is a circular gallery featuring dozens of participatory exhibits in the physical and natural sciences. On the Science Center's lower level is the Discovery Room with hands-on science activities for children, the Computer Connection multistation computer lab, and the Science Showplace at which a variety of live science stage demonstrations are conducted. *Carolyn Collins Petersen.*

observatory. *Open after 3 p.m., evening viewing begins at twilight, call ahead; adults $2.*

Portland

H. C. Kendall Planetarium. Oregon Museum of Science and Industry, 4015 S.W. Canyon Road, 97221-2797. Dr. Jan P. Dabrowski, (503) 222-2828.
Major astronomy education resource for the northwest, astronomy and space science exhibits and programs. Planetarium shows: "Cosmic Fury," "Current Night Sky," tour following last Friday show. *Open (June 20-September 7) Saturday-Thursday 9 a.m.-5 p.m., Friday 9 a.m.-8 p.m.; shows daily 11 a.m., 1, and 3 p.m., plus 6:15 p.m. on Friday; adults $4 (museum), $.50 (shows).*

PENNSYLVANIA

Harrisburg

State Museum of Pennsylvania Planetarium. 3rd and North Street, 17108. Jeffrey L. Smith, (717) 783-9914.
Planetarium shows: "To Jupiter and Beyond" (through June 28), "The Summer Sky" (July 2-September 6). *Open Tuesday-Saturday 9 a.m.-5 p.m., Sunday 12-5 p.m.; shows Saturday-Sunday 1:30 and 3:00 p.m., weekdays 2 p.m.; adults $1.*

National Radio Astronomy Observatory, Green Bank, West Virginia

Lancaster

North Museum Planetarium and Joseph Grundy Observatory. Franklin and Marshall College, 17604. Jordan Marche, (717) 291-3941.
Planetarium programs: "Time, Space, and the Stars" (June 1-7), schedule for rest of summer to be announced. Public observing at observatory (on Baker campus) first and third Friday evenings of month. Summer Stargaze August 1. Small meteorite display, discovery room in museum. *Museum open Wednesday-Saturday 9 a.m.-5 p.m., Sunday 1:30-5 p.m.; discovery room open Saturday-Sunday 1:30-4:30 p.m.*

Philadelphia

Franklin Institute Science Museum and Fels Planetarium. 20th Street and the Parkway, 19103. (215) 448-1200.
Traveling exhibit: "Robots and Beyond: The Age of Intelligent Machines" (June 27-August 30).

Pittsburgh

Allegheny Observatory. 159 Riverview Avenue, 15214. Nancy Robinson, (412) 321-2400.
Thaw 30-inch photographic refractor, historic 13-inch Fitz-Brashear. Daytime tours Monday-Friday 1 p.m., with slide show, lecture; evening tours Wednesday, Thursday, and Friday 8 p.m. *Reservations required.*

Villanova

Planetarium and Observatory. Department of Astronomy and Astrophysics, Villanova University, 19085. (215) 645-4820.
Visits by arrangement only.

RHODE ISLAND

Providence

Cormack Planetarium. Museum, Roger Williams Park, 02905. Francine Jackson, (401) 785-9450.
Planetarium programs Saturday and Sunday at 1, 2, 3, and 4 p.m.

Ladd Observatory. 210 Doyle Avenue, 02912. Hendrik J. Gerritsen, (401) 863-1488.
Antique instruments, transparency room.

SOUTH CAROLINA

Columbia

Gibbes Planetarium. 1112 Bull Street, 29201. Stephen D. Morgan, (803) 799-2810.
Planetarium programs, astronomy exhibits. *Programs Saturday-Sunday 2, 3, and 4 p.m.; art museum open 1-5 p.m.; adults $2 (museum), includes planetarium shows.*

Florence

Planetarium. Francis Marion College, 29501. Ed Dooley (803) 661-1250.
Planetarium programs: "Springtime of the Universe" (June 14, 28), "It's about Time" (July 12, 26; August 9, 23); observatory. *Show 3 p.m., observatory open at irregular intervals.*

TENNESSEE

Memphis

Memphis Pink Palace Museum and Planetarium. 3050 Central Avenue, 38111. George Brown, (901) 454-5609.
Meteorite, Tektite, and Shattercone exhibits, astronomy workshops. Planetarium shows: "Egypt's Eternal Skies" (June 1-August 30), "Starlit Nights" (July 14-August 30). *"Egypt" Saturday 11 a.m., 1:30 and 2:45 p.m., Sunday 1:30, 2:45 and 4 p.m.; after June 9 also Tuesday-Friday 11 a.m. and 1:30 p.m.; July 14-August 30 Tuesday-Sunday 1:30 p.m. only; "Starlit" Saturday 11 a.m. and 2:45 p.m., Sunday 2:45 and 4 p.m., Tuesday-Friday 11 a.m.*

Nashville

Dyer Observatory. Vanderbilt University, 37235. Douglas S. Hall, (615) 373-4897.
Observatory programs and observing of Saturn (May 28, June 25, and July 16) 8:30-10 p.m. University's Stevenson Center Observatory open for observing (June 5, 8:30-9:30 p.m.; June 26, 12-2 p.m.; July 3, 8:30-9:30 p.m.; August 31, 8:30-9:30 p.m.)

Sudekum Planetarium. Cumberland Museum and Science Center, 800 Ridley Boulevard. (615) 259-6383.

TEXAS

Amarillo

Don Harrington Discovery Center. 1200 Streit Drive, 79106. Robert W. Bauman, Jr., (806) 355-9547.
Planetarium programs: "Skywatchers of Ancient Mexico" (June 1-August 31) in conjunction with exhibit of rare Mexican masks, daily 2 p.m. and Friday 8:30 p.m.; "Night Sky Programs" (June 1-August 31) daily 1 p.m.; public observing (June 20) 10 p.m. *Open Tuesday-Saturday 9 a.m.-5 p.m., Sunday 12-5 p.m., Friday 7-9 p.m.*

Corpus Christi

King High School Planetarium. 5225 Gollihar Road, 78412. Robert Wollman, (512) 992-0942.
Planetarium shows June 2 and 9, August 18 and 25. Guided observing with binoculars and telescopes. *Shows 7:30 p.m.; adults $2.*

Dallas

The Science Place Planetarium. 1620 First Avenue (in Fair Park), 75210. (214) 428-7200.
Exhibits, planetarium programs. *Open*

NEW YORK

American Museum-Hayden Planetarium

The American Museum-Hayden Planetarium is one of the best-known star theaters in the United States. Since its opening in 1935, the Hayden has entertained and educated more than 25 million visitors from around the world.

Program offerings at the Hayden include star shows, classes, and concerts. Many of the shows are given in the Sky Theater, which is equipped with a Zeiss Mark VI star projector and a computer automation system controlling over one hundred special effects. The theater — among the largest in the country — seats 650 under a 75-foot dome. In addition to regular star shows, the Hayden also offers laser shows.

Two special exhibits surround the Sky Theater. The "Hall of the Sun" is devoted to the Sun's physical features and its effects on the rest of the solar system. "Astromania" is a display combining astronomical facts, history, and fancy.

Below the Sky Theater on the first floor of the facility is the Guggenheim Space Theater, a circular area where special slide-tape programs introduce visitors to astronomical and space science topics. On the ceiling of the Guggenheim is one of the largest moving models of the solar system. The 14-ton "Willamette" meteorite, the largest ever found in the United States, is on permanent display. *Carolyn Collins Petersen.*

WASHINGTON

Goldendale Observatory

Imagine yourself and a 24.5-inch Cassegrain reflector on a hilltop in southern Washington state with the whole night ahead of you to observe whatever you like.

At Goldendale Observatory in Goldendale Observatory State Park amateur astronomers can reserve the public telescope for their own observing programs after 11 p.m. Before 11 p.m. all visitors can enjoy guided tours of the universe through the telescope.

Stephen Stout, astronomy specialist at Goldendale, gives three programs five days a week during the summer. The program includes a demonstration of how to use telescopes (half a dozen portable scopes are available for visitors); a walking tour of the grounds and a history of the observatory; practical astronomy and basic astronomy demonstrations; Moon, planetary, and deep-sky observing on the 24.5-inch scope; and naked-eye constellation observing.

The afternoon program features observations of the Sun and of planets bright enough to be seen. The observatory also has a theater for demonstrations and videos on astronomical topics for those inevitable cloudy nights.

A gathering place for amateur astronomers throughout the Pacific Northwest, Goldendale is one hundred miles east of Portland, Oregon, and two hundred miles southeast of Seattle, Washington. (See the listing below for details about reserving the public telescope.) *Kristine R. Majdacic.*

Tuesday-Saturday 9 a.m.-5 p.m., Sunday 12-5 p.m.; shows Tuesday-Friday 3 p.m., Saturday-Sunday 1, 2, 3, p.m.; adults $2.

El Paso

El Paso Independent School District Planetarium. 6531 Boeing Drive, 79998. John R. Peterson, (915) 779-4317.
Astronomy and space science programs, NASA displays and models, meteorite collection, several telescopes. *Open 8 a.m.-4:30 p.m.*

Fort Davis

McDonald Observatory. P.O. Box 1337, 79734-1337. Robert Stanley, (915) 426-3263.
Visitors' center with astronomy exhibits, films, open Monday-Sunday 9 a.m.-5 p.m. Solar viewing of active sunspots and the Moon Friday-Tuesday 11 a.m. Observatory tours daily 9:30 a.m. and 2 p.m. Star parties Tuesday and Saturday evenings.

Fort Worth

Noble Planetarium. Fort Worth Museum of Science and History, 1501 Montgomery Street, 76107. Michael P. Walker, (817) 732-1631.
Planetarium programs: "Cosmic Dimensions," "Star Travelers" (family show), "Texas Sky," summer laser magic matinees (May 25-September 7). *Day and evening shows; admission $1.50-$4; children under four not admitted to astronomy programs except "Star Travelers."*

Houston

Lyndon B. Johnson Space Center. 2101 NASA Road 1, 77058. Charles A. Biggs, (713) 483-4241.
Space hardware, Skylab trainers, Space Shuttle Orbiter trainers, lunar sample building, Mission Control Center briefings. *Open daily 9 a.m.-4 p.m.*

Odessa

Odessa Meteor Crater. P.O. Box 3626, 79760 (ten miles from Odessa).
Second largest meteor crater, museum, nature trail.

San Angelo

University Planetarium. Angelo State University, 76909. Mark Sonntag, (915) 942-2188.

UTAH

Salt Lake City

Hansen Planetarium. 15 South State Street, 84111-1590. (801) 538-2104.
Planetarium shows: "Galaxies" (through June 7), "Zap" (July 1-December 1). Magic under the stars children's festivities (Saturdays in August). Space science exhibits. *Open Monday-Saturday 10 a.m.-8 p.m., Sunday 1-6 p.m.; shows Monday-Saturday 11 a.m., 2, 4:30, and 7 p.m., Sunday 2 and 4:30 p.m.; star show, adults $3.*

VERMONT

St. Johnsbury

Fairbanks Museum and Planetarium. Main Street, 05819. Mark Breen, (802) 748-2372.
Planetarium blacklight exhibit hall with hands-on exhibits on gravity and lunar orbit, planet orrery, and multiple star display. "Humanities and the Stars" series (July). Star party for the Perseid meteor shower in August. *Shows Saturday-Sunday 2:30 p.m. (June 1-June 30), daily 2:30 p.m. and weekdays 11 a.m. (July 1-August 31); adults $2 (museum), $1 (planetarium); not recommended for children under five.*

VIRGINIA

Charlottesville

Leander McCormick Observatory. P.O. Box 3818, University of Virginia, 22903-0811. (804) 924-7494.
Visitors' nights: observing with 26-inch Clark refractor, lecture, exhibits of current research. *First and third Friday of every month sundown to 11 p.m.*

Fort Union

Wicker Planetarium. Fort Union Military Academy, Route 15, P.O. Box 278, 23055. Major Billy C. Ozment, (804) 842-3082.
Public programs presented upon request.

Hampton

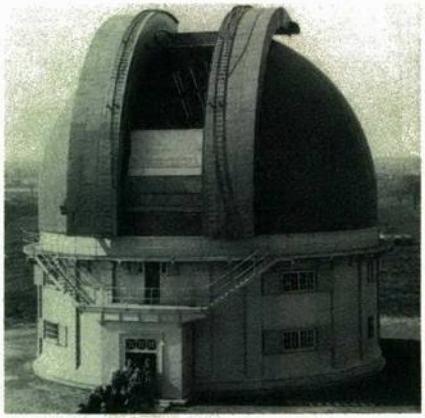
Langley Research Center. NASA Langley Visitor Center, Mail Stop 480, 23665-5225. (804) 865-2855.
Self-guided tours, films, videos. *Open daily 8:30 a.m.-4:30 p.m., Sunday 12-4:30 p.m.; guided tours and educational programs by reservation.*

Harrisonburg

John C. Wells Planetarium. James Madison University, 22807. John C. Wells, (703) 568-6109 (day), (703) 434-6283 (evening).
Planetarium program: "Summer Skies." *Shows 7:15 and 8:15 p.m. June 22, July 6, 9, 13, 16, 20, 23, 27, 30.*

Newport News

Peninsula Planetarium-Virginia Living Museum. 524 J. Clyde Morris Boulevard, 23601. Jon Bell, (804) 595-1900.
Public programs daily, constellation identification, observing after programs (filters for solar observing). *Museum open Monday-Saturday 9 a.m.-6 p.m., plus Thursday 7-9 p.m., Sunday 10 a.m.-6 p.m., adults $4; shows Monday-Sunday 11 a.m., 1:30, 2:30, 3:30, and 4:30 p.m., 7:30 p.m. Thursday, adults $2; combination planetarium/museum $5.*



David Dunlap Observatory, Richmond Hill, Ontario, Canada

Richmond

Science Museum of Virginia/UNIVERSE Space Theater. 2500 West Broad Street, 23220. Margaret D. Austin, (804) 257-1657.
Planetarium programs. Monthly observing sessions third Friday 9 p.m. (April-October). OMNIMAX films, astronomy exhibits, telescopes. *Open daily 11:30 a.m.-8 p.m.; adults, $2 (exhibit area), $4 (OMNIMAX and planetarium programs).*

Virginia Beach

Virginia Beach City Public Schools Planetarium. 3080 South Lynnhaven Road, 23452. H. D. Teuscher, (804) 486-1855.
Telescope observing, NASA Apollo Command Module, Saturn V rocket, laser usage display, showcase of weather. Planetarium shows: "Dawn of Astronomy" (June), "Traveling through the Solar System" (August). *Shows at 7 p.m. Sunday and Tuesday; observing on selected evenings.*

Wallops Island

Wallops Flight Center. 23337. Keith Koehler, (804) 824-2298.
Spacecraft and flight articles exhibits, movies and video presentations, rocket and satellite models, Moon rock. *Open Thursday-Monday 10 a.m.-4 p.m.*

WASHINGTON

Goldendale

Goldendale Observatory. Goldendale Observatory State Park, 1602 Observatory Drive, 98620. Stephen Stout, (509) 773-3141.

Tours, telescope viewing, programs. (See profile on page 52). *Open Wednesday-Sunday 1-5 p.m. and 7-11 p.m.; programs 1:15, 3, and 7:15 p.m.; reservations required for large groups and overnight observing.*

Seattle

Pacific Science Center. 200 Second Avenue, 98109. Chaz Hafey, (206) 443-2881.
Star Lab Planetarium show: "Star Hunt" hourly 11 a.m.-5 p.m. Science demonstrations hourly 11 a.m.-5 p.m. IMAX Theater: "The Dream Is Alive." Museum exhibits. *Open daily 10 a.m.-6 p.m., adults $4.50 (includes IMAX theater).*

Spokane

Eastern Washington Science Center. Riverfront Park, 99202. Eileen Starr, (509) 359-6391.
Astronomy exhibits, demonstrations. *Open daily 11 a.m.-6 p.m.; adults $2.50.*

WEST VIRGINIA

Davis

Blackwater Falls State Park. P.O. Box 490, 26260. Pat Northeimer, (304) 259-5216.
Stargazing activities June 27, 9 p.m.; July 25, 9 p.m.; August 29, 8:30 p.m.

Green Bank

National Radio Astronomy Observatory. P.O. Box 2, 24944-0002. R. L. Fleming, (304) 456-2011.
Free summer tours daily, audiovisual presentation on radio astronomy, narrated bus tours include stops at several major telescopes such as the 140-foot and three 85-foot diameter antennas, which form part of an interferometer system. *Tours hourly 9 a.m.-4 p.m.*

Yerkes Observatory, Williams Bay, Wisconsin

WISCONSIN

Madison

Washburn Observatory. 1401 Observatory Drive, 53706. (608) 262-3071.
Telescope viewing, astronomer on duty to answer questions. *Open Wednesday 9 p.m. June 17-August 5.*

Milwaukee

University of Wisconsin — Milwaukee Planetarium. 1900 East Kenwood, 53211.
Tours available Friday 7 and 8:15 p.m.; adults $1; children under six not admitted.

Williams Bay

Yerkes Observatory. 373 Geneva Street, 53191-0258. Richard Dreiser, (414) 245-5555.
Saturday tours, meteorite exhibit, Warner and Swasey Filar Micrometer, largest refractor telescope in the world (40-inch diameter). *Tours Saturday (June 1-September 30) 1:30, 2:15, and 3 p.m.*

CANADA

Alberta

Edmonton Space Sciences Centre. 11211-142 Street, T5M 4A1. (403) 451-7722.
Planetarium Star Theater, IMAX Theater, public observatory open Wednesday-Sunday July-August.

British Columbia

Dominion Radio Astrophysical Observatory. National Research Council of Canada, White Lake Road, P.O. Box 248, Penticon, V2A 6K3. Dr. Lloyd A. Higgs, (604) 497-5321.
Tours of radio telescope, laboratories, computers. *Tours Sunday 2-5 p.m. July and August.*

Gordon Southam Observatory. 1100 Chestnut Street, Vancouver, V6J 3J9. David Dodge, (604) 738-2855.
Telescope viewing, courses, programs. "Shoot the Moon" program for those with 35mm SLR cameras (usually First Quarter Moon). Satellite receiving system monitors NASA and space science broadcasts (when available) for public viewing. *Observatory open weekends (June), Tuesday-Sunday (July-August).*

H. R. MacMillan Planetarium. 1100 Chestnut Street, Vancouver, V6J 3J9. David Hurd, (604) 736-4431.
Planetarium show: "Grog's Universe" for children, amateur astronomy shows, laser/music show, family show. *Family show 1 p.m. (June weekends), daily (July-August); amateur shows daily 2:30, 4, and 8 p.m.; laser shows Friday-Saturday 10:45 p.m.; children under eight not admitted to evening show; adults $4, laser show $5; advance ticket purchase recommended.*

Climenhaga Observatory. Department of Physics, University of Victoria, P.O. Box 1700, Victoria, V8W 2Y2. Russ Robb, (604) 721-7750.
Viewing with 20-inch telescope, 8-inch heliostat for viewing the Sun, tours of the telescopes. *Call ahead for tours.*

Dominion Astrophysical Observatory. 5071 West Saanich Road, Victoria, V8X 4M6. (604) 388-0012.
Tours, astronomy displays, models. *Open Monday-Friday 9:15 a.m.-4:30 p.m., Saturday 9 a.m.-11 p.m., Sunday 9 a.m.-8 p.m.; public talk and observing Saturday 9-11 p.m.; reservations required for group tours.*

Manitoba

Manitoba Museum of Man and Nature and Planetarium. 190 Rupert Avenue, Winnipeg, R3B 0N2. (204) 956-2830.
Touch the Universe exhibit, museum, concert hall. Planetarium show: "Beyond the Fourth Dimension" (through June 7), "Halfway to Anywhere." *Shows Tuesday-Friday 3 and 7:45 p.m., Saturday, Sunday, and holidays 1, 2:30, 4, and 7:45 p.m.; adults $3.50.*

Nova Scotia

Burke-Gaffney Observatory. Department of Astronomy, St. Mary's University, Halifax, B3H 3C3. Laurie Reed, (902) 429-9780 extension 2184.
Tours of and observing with 40-cm Cassegrain reflecting telescope, slide shows, 150-piece stamp collection commemorating the five hundredth anniversary of the birth of Copernicus. *Open Saturday 9 p.m.*

Ontario

David Dunlap Observatory. Department of Astronomy, University of Toronto, 123 Hillsview Drive, Richmond Hill. (416) 884-2112.
Tours and viewing through 74-inch telescope Saturday evening by reservation only.

McLaughlin Planetarium at the Royal Ontario Museum. 100 Queen's Park, Toronto, M5S 2C6. Jocelyn Wiley, (416) 586-5565.
Star shows, laser shows, Astrocentre gallery. Stargazing workshops 7-9 p.m. nonholiday Mondays, adults $6. (See profile below.) *Museum open 10 a.m.-6 p.m. daily, until 8 p.m. Tuesday and Thursday; adults $3.*

Ontario Science Centre. 770 Don Mills Road, Toronto, M3C 1T3. Martha McGloin, (416) 429-4100 extension 255.
"Exploring Space" hall includes meteorite, Moon landing, and Milky Way exhibits. Planetarium presentation: "Starlab." *Open daily 10 a.m.-6 p.m., until 9 p.m. Friday; adults $3.50, family $8.*

Saskatchewan

University of Saskatchewan Observatory. Saskatoon, S7N 0W0. Stan Shadick, (306) 966-6434.
Astronomical museum, observing. *Open house Wednesday 10-11:30 p.m. (June-July), Saturday 9:30-11:30 p.m. (August).*

ONTARIO, CANADA

McLaughlin Planetarium's Astrocentre

Opened in December 1986, the new Astrocentre gallery of the McLaughlin Planetarium, adjoining the Royal Ontario Museum in Toronto, features dramatic displays and hands-on exhibits, including a solar telescope, stellarium, and orrery.

With the solar telescope you can view the Sun — and any flares and prominences occurring that day — through a red, Hydrogen-alpha filter. On cloudy days a monitor displays a videotape of the Sun, recorded on the most recent sunny day. The stellarium is a rotating, scale model of 787 stars within 50 light-years of the Sun in a display eight feet in diameter.

The two-dimensional orrery shows the relative orbital speeds of the planets around the Sun with lighted pathways on twenty-foot-wide panels.

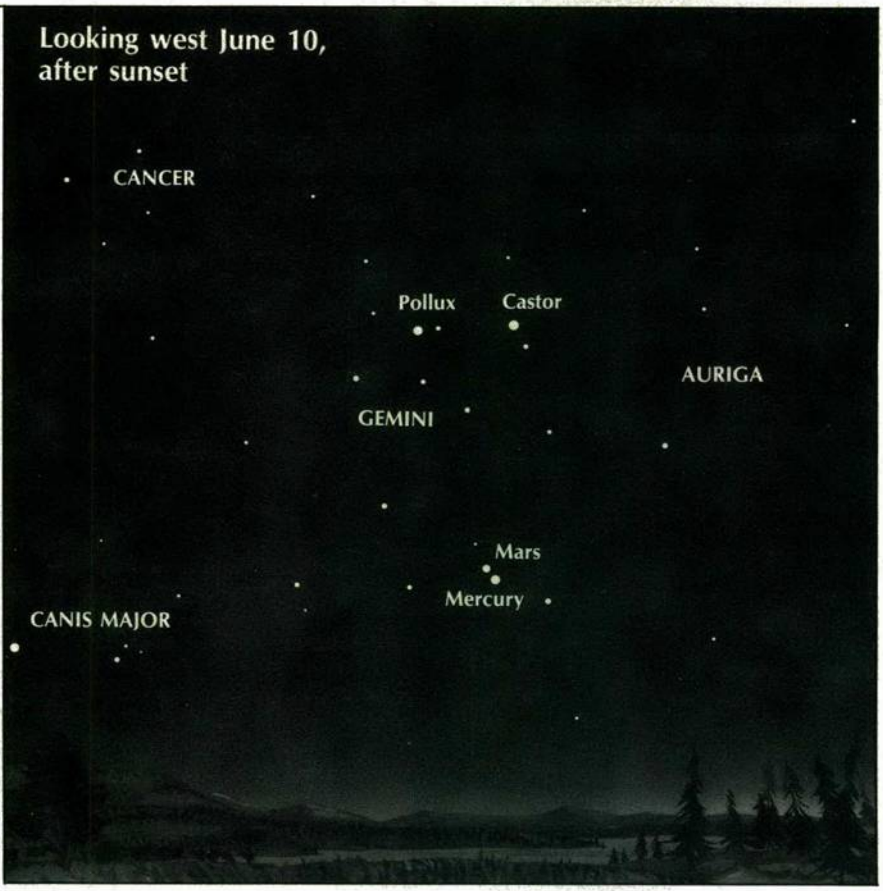
The Astrocentre also features exhibits on the Sun, the solar system, "vagabonds" (comets, meteors, and asteroids), tools of early skywatchers, stars, and galaxies.

Astronomy programs are projected on the 92-foot screen dome of the McLaughlin Planetarium. This summer's feature is on the mythology of astrology. Also offered through the planetarium are astronomy courses, laser shows, and an astronomy hotline.

The adjoining Royal Ontario Museum has extensive natural history and history of man galleries, plus art courses, tours, and lectures. *Betty Robinson.*

A Summer Panorama

by Robert Burnham



The Wanderers

If you wish to see **Mercury** this summer, your best opportunity will come the first week of June. At this time the planet is at its greatest separation from the Sun and lies low in the west-northwest an hour after sunset. Mercury's 0.5 magnitude makes it brighter than any star in that part of the sky. Because of its low elevation, it will have a slight reddish tinge.

Since Mercury will be only 11° high at best visibility (June 3), houses or trees will probably obstruct your view of this elusive planet. For a clear view go to a nearby park, ball field, or schoolyard. On June 10, Mercury will be one Moon-diameter away from **Mars**, then at magnitude 1.8, which is roughly half as bright as Mercury. Mars lies to the upper left of Mercury and has a distinct orange color stronger than that of Mercury.

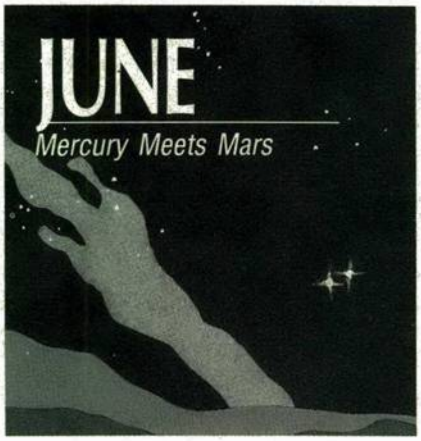
From late May until June 10, sharp-eyed observers will notice Mercury climbing slowly, day by day, away from the horizon as if to greet Mars, which is slipping lower. A set of snapshots taken with a tripod-steadied telephoto at the same time of evening over a week or two will yield a pleasing series of photographs showing planetary motion — a celestial "home movie." Use fast film (slide or print) and set the aperture wide open and the focus at infinity. Try exposures of 1, 2, 5, and 10 seconds.

By the end of June Mercury will be out of sight as it nears inferior conjunction (when Mercury passes between the Earth and the Sun), which occurs on July 4. Unfortunately Mercury's visibility in the morning sky during July and August is only so-so, because the planet won't reach as high an elevation as it did in June. Look for it in the east-northeast from the middle of July until the first week of August. After about August 10, it will be too low to be seen easily.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Mars remains visible through June but vanishes from view in the early part of July. It is in conjunction with the Sun on August 25 and won't return to visibility until October, when it appears low in the east before sunrise.

As Mars sets, look east to see **Saturn** rising with the stellar background of Ophiuchus and Scorpius. Saturn has an ivory-white color and at magnitude 0.0 (about the same as Mercury) it shines about half a magnitude brighter than Antares, the bright amber star in the Scorpion. On June 9, Saturn is opposite the Sun in the sky — a position called (naturally!) opposition — and on the 11th, the Full Moon passes south of the planet.

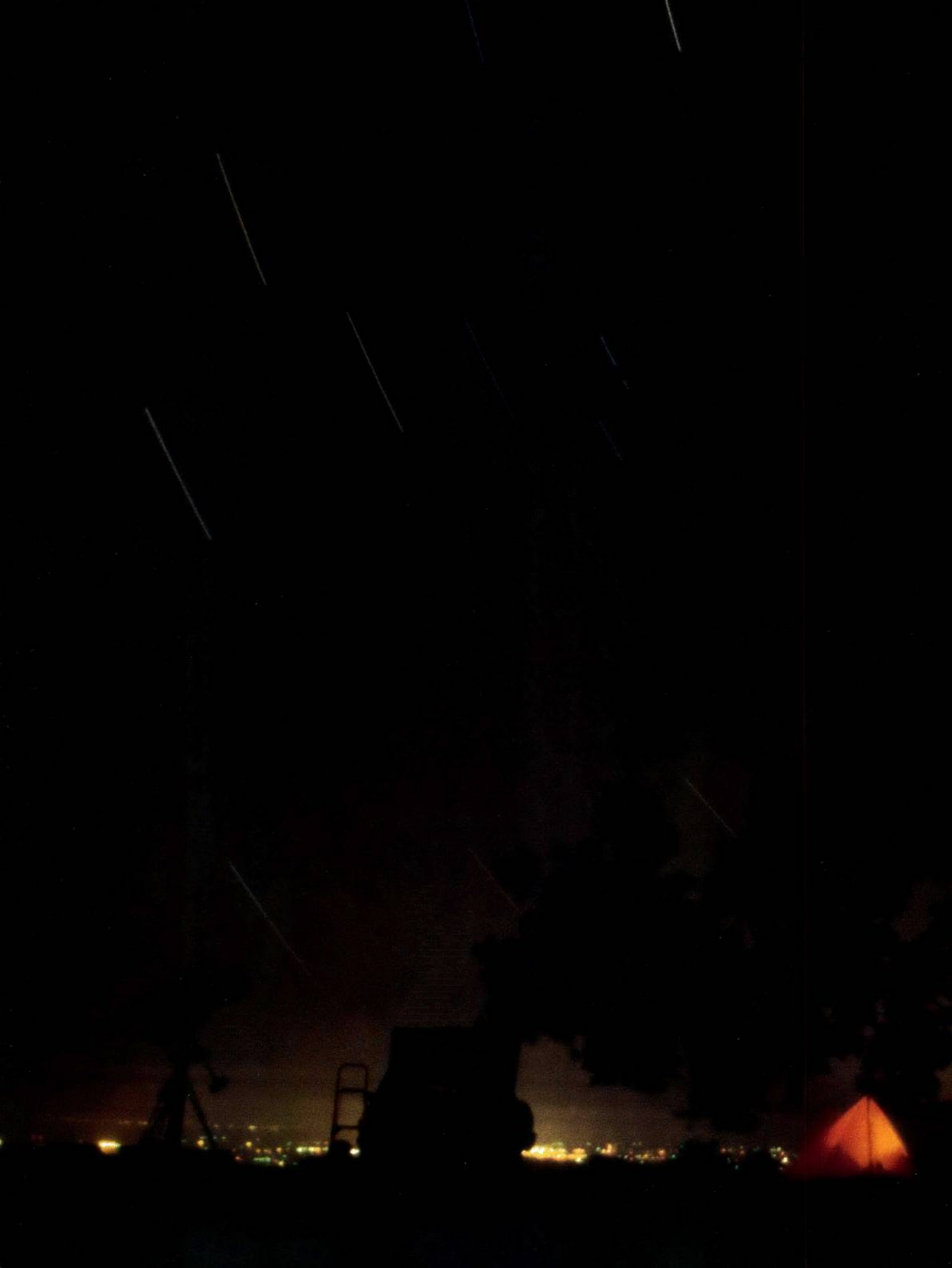


Opposite page: California amateur Jim Baumgardt took this 20-minute exposure of his camp as he prepared for a night's observing from Fremont Peak in northern California.

Because it is ten times farther from the Sun than the Earth is, Saturn moves among the stars very slowly. Therefore it holds nearly the same celestial position all summer, moving just slightly westward toward Antares from where you see it tonight. In June this part of the sky lies in the southeast at dusk; in July it will be directly south, and by August it will have shifted into the southwest at dusk. Yet Saturn's position relative to Antares will change little.

Two naked-eye planets remain to be located — Jupiter and Venus. Although in June **Jupiter** is rising by 3 a.m., you should wait until morning twilight begins so you can catch Venus as well. After the conjunction in early May between these two planets, Jupiter continued to rise higher each morning, while Venus slowly dropped. Jupiter has a magnitude of −2.2 and lies among the stars of Pisces. But because this region of sky contains no bright stars, Jupiter stands alone, shining with an unmistakable white gleam.

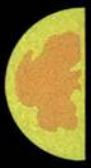
During the next two months Jupiter will glide slightly eastward, but lacking nearby background stars with which to gauge its progress, you will probably not even



June Night Sky

First Quarter
June 4
2:53 p.m. EDT

Full Moon
June 11
4:49 p.m. EDT



Last Quarter
June 18
7:02 a.m. EDT

New Moon
June 26
1:37 a.m. EDT

3rd Mercury is at its greatest visibility in the evening sky for this elongation; it remains in view low in the west-northwest during the hour after sunset until about the 21st.

4th First Quarter Moon is at 2:53 p.m. EDT.

7th Mercury is at greatest eastern elongation in the evening sky. The Moon passes north of Spica, occulting it for viewers in Greenland, Europe, and northern Africa.

9th Saturn is at opposition in Ophiuchus and visible all night.

10th Mars and Mercury lie close together in the evening sky. The Moon passes close to Antares, occulting it for viewers in Central and South America.

11th Full Moon occurs at 4:49 p.m. EDT.

12th The Moon is closest to Earth at 9:14 p.m. EDT: 223,210 miles (359,211 kilometers).

16th Uranus is at opposition in Ophiuchus.

18th Last Quarter Moon is at 7:02 a.m. EDT.

21st The solstice occurs at 6:11 p.m. EDT and summer begins in the Northern Hemisphere.

26th New Moon is at 1:37 a.m. EDT.

28th The Moon is farthest from Earth at 12:16 a.m. EDT: 252,543 miles (406,417 kilometers). Neptune is at opposition in Sagittarius.

JULY PREVIEW

11th Mercury lies 5° south of Venus in the predawn sky.

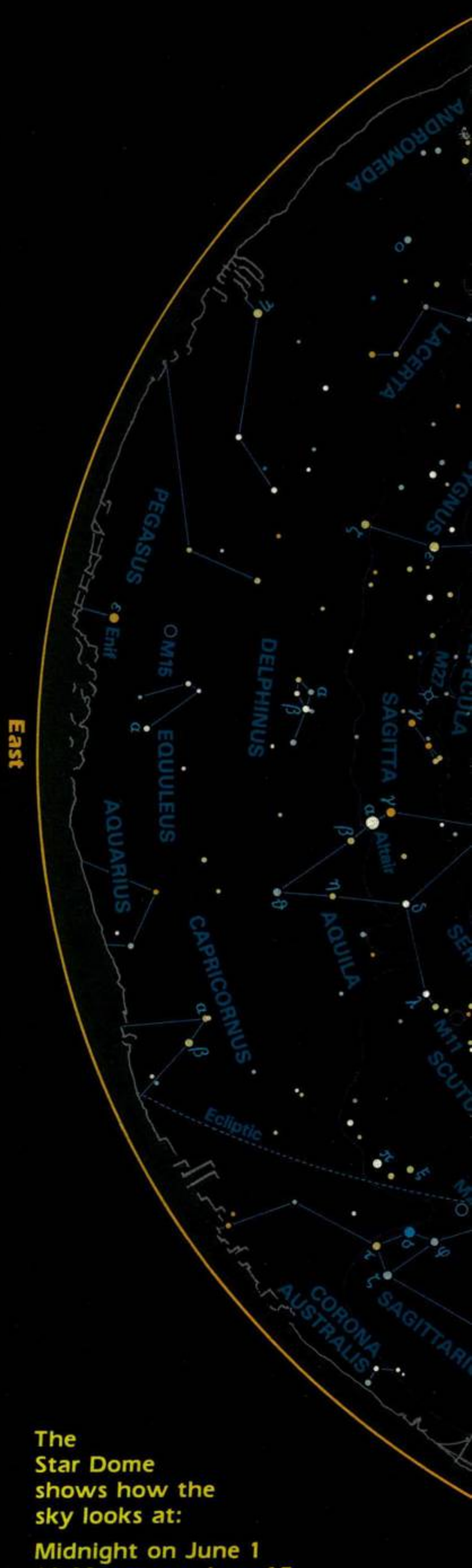
18th The Moon passes 4° north of Jupiter in the morning sky.

29th The southern Delta Aquarid meteors are at peak activity in the predawn hours. Expect about twelve to twenty meteors an hour from a moderately dark site.

AUGUST PREVIEW

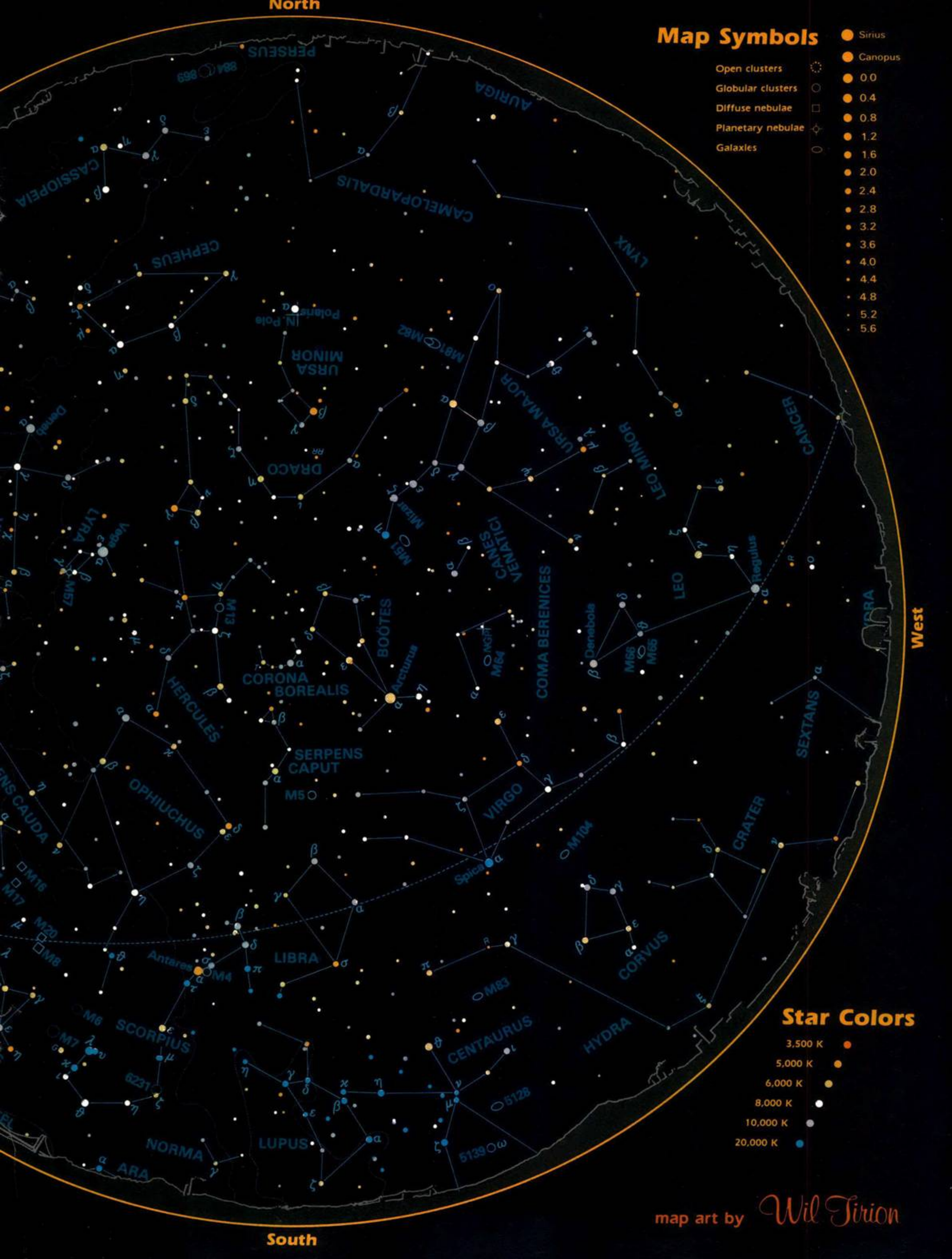
13th The famous Perseid meteors reach peak activity in the predawn hours today, but the Moon will brighten the skies and wash out many of them. Look for about fifteen to twenty meteors per hour at a dark-sky site.

28th An occultation of Spica by the Moon is visible in the evening across most of the United States, except in New England, New York, most of northeastern Pennsylvania, and west of the Rocky Mountains.



The Star Dome shows how the sky looks at:

Midnight on June 1
11:00 p.m. on June 15
10:00 p.m. on June 30
9:00 p.m. on July 15


North
South
West
Map Symbols
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
PERSEUS
884
869
AURIGA
CASSIOPEIA
CAMELOPARDALIS
CEPHEUS
LYNX
Polaris
N. Pole
URSA MINOR
M81
M82
URSA MAJOR
CANCER
LEO MINOR
Deneb
DRACO
RR
Mizar
M51
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LYRA
Vega
M57
M13
HERCULES
BOÖTES
CORONA BOREALIS
Arcturus
COMA BERENICES
M64
NGC
LEO
Regulus
Denebola
M66
M65
HYDRA
SERPENS CAPUT
M5
OPHIUCHUS
SERPENS CAUDA
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CRATER
M104
Spica
M16
M17
M20
M8
LIBRA
Antares
M4
CORVUS
M83
M6
M7
SCORPIUS
CENTAURUS
HYDRA
6231
5128
LUPUS
NORMA
ARA
5139

map art by Wil Tirion

Opposite page, top: A twilight view overlooking Griffith Observatory in Los Angeles. Photo by Mark Erickson.

Opposite page, bottom: The Moon and Jupiter are poised in a tranquil sky over the parabolic dishes of the Very Large Array near Socorro, New Mexico. Photo by Geoff Chester.

notice the motion. However, by the middle of July you will notice that Jupiter is rising around midnight and, a month later, is in view by 10 p.m. By Labor Day it rises soon after evening twilight ends.

In June, at a time when morning twilight seems to strengthen minute by minute, you can spy **Venus** low in the east. (You may need that park or schoolyard again to get a low enough horizon.) Venus is at magnitude −3.9 and shines clear white. June is about the last month to see it because sometime in July it drops down too close to the Sun. Venus passes superior conjunction with the Sun on August 23 and won't reappear in the evening sky until early October.

JULY
Delta Aquarid Meteor Shower

Summertime is ideal for meteor observing — it seems easy to stay up all night and watch the meteors "pop" in the wee hours. June is barren of strong displays, but one occurs both in July and August: the Delta Aquarids of late July and the famed Perseids of mid-August. The **Delta Aquarid** shower promises to be the better of the two, with a peak hourly rate of twelve to twenty meteors seen from a fairly dark-sky site on July 29. (The shower's radiant lies near the star Delta [δ] in Aquarius, hence the name.) But, though the peak falls on the 29th, the shower is a very broad one, and many Delta Aquarids can be seen a week earlier or later. (Because the Moon is just after New, it won't interfere much.)

Probably as many people know of the **Perseids** as know of the Big Dipper. This year peak Perseid activity comes on August 13, with fifteen to twenty meteors an hour visible from a suburban location. The Moon, unfortunately, will be a real hindrance, because the shower occurs halfway between Full and Last Quarter. The bright meteors will be diminished, while the faint meteors will be washed out altogether. The real loss, though, will be in meteor photography, because the bright sky background will force you to make short exposures to avoid fogging the film.

The shower radiant lies near the Double Cluster between Perseus and Cassiopeia. Because it's circumpolar from most U.S. and all Canadian latitudes, the radiant remains visible the whole night but reaches highest elevation after morning twilight is well under way.

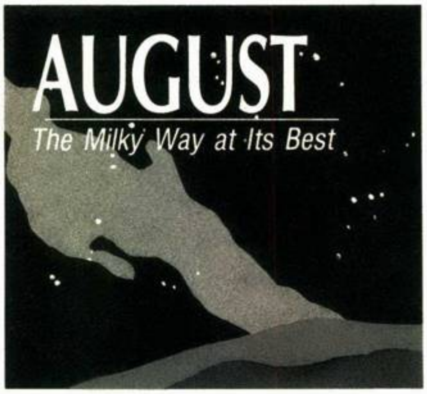
The Starry Sky

For most people the summer heavens are synonymous with the **Milky Way**. Not only are its brightest portions visible, but for most people summer offers the one chance each year to see the Milky Way under truly dark skies. How many have ever seen the Milky Way reflected in the still water of a backwoods lake? Or traced its silvery length rising over trees lit by a flickering campfire? If you can't make such an experience part of your summer plans this year, why not explore the dark skies of the countryside around the town where you live? Take a jacket, a flashlight dimmed with red paper, your ASTRONOMY, and some bug repellent.

In the late evening, spring stars fill the western half of the June sky, while summer objects occupy the eastern half. If you face west, you'll see a 1st-magnitude white star, Regulus, belonging to **Leo** the Lion. Above Regulus a right triangle has 2nd-magnitude Denebola at its upper tip, which marks Leo's haunches. Catch your last views of Leo now, for as summer progresses the sky will wheel westward and tip him below the horizon for another year.

To Leo's upper right the familiar Big Dipper descends bowl-first as it swings under the pole. Using the star map and the Dipper, try to trace the rest of the Great Bear **Ursa Major**, and from it locate the Small Bear **Ursa Minor** dangling by its tail star, Polaris. Now take the arc of the Dipper's handle and follow it outward to a yellow star named Arcturus in **Bootes** the Herdsman. A small step farther south from Arcturus brings you to Spica in **Virgo** the Maiden. Using Regulus, Arcturus, and Spica as benchmarks, you can locate most of spring's constellations easily.

Spica and Regulus lie near the ecliptic, the imaginary track along which you find the Sun and the planets. (The map shows it as a dashed line.) Eastward from Spica the ecliptic passes **Libra** the Balance, which has a distinct diamond shape under a dark sky but is severely diminished under a bright city or suburban sky. Then the ecliptic greets **Scorpius** the Scorpion. The long "baling hook" profile of Scorpius is a recognizable figure. If you have binoculars, look next to amber-colored Antares; M-4 is an easy-to-find globular cluster, and several other star clusters lie near Lambda (λ), called Shaula, the "stinger" star.


AUGUST
The Milky Way at Its Best

June is the best time to examine a southern figure to the lower right of Scorpius: **Lupus** the Wolf, created by the Greeks and supposedly representing an animal held in the grip of **Centaurus** the Centaur, which lies immediately to Lupus' right. The Wolf contains several objects for telescope owners (Eta [η] is a nice double star, for example) but little more for naked-eye observers than the fun of viewing an exotic "Southern Hemisphere" constellation from home.

Ivory-white Saturn, a temporary resident of **Ophiuchus** the Snake Bearer, shines to the left of Antares. (Ophiuchus isn't an official member of the zodiac but straddles it anyway.) The Snake Bearer always seems rather nondescript because its bell profile gets lost between bright Scorpius and compact **Hercules**, which lies directly north of it. Hercules' keystone might be confused with the head of **Draco** the Dragon, but the latter is smaller and dimmer. From the keystone body Hercules' arms run down toward Ophiuchus, while his legs point toward Draco (yes, he's upside down!).

Hercules' neighbor on the east is rhomboidal **Lyra** the Lyre. Lyra's 1st-magnitude star Vega is a landmark of the summer star groups. Another landmark is Deneb, the star at the tail of the Swan **Cygnus**, depicted flying southward along the Milky Way. Cygnus' shape also gives rise to its other name, the Northern Cross. **Aquila** the Eagle, another bird aimed south, lies to the right of Cygnus as you face east; its wings make a tall diamond and a very uneaglelike neck stretches south. Aquila's brightest star is Altair.

Rising in the southeast by 10 p.m. (in June) is **Sagittarius** the Archer. By late July and early August the Archer will be crossing the meridian at this time and will dominate southern horizon views much as Scorpius does tonight. Among the more northerly groups you will see Aquila, Cygnus, and the rest of the figures along the Milky Way all summer. Only in late fall, when the Sun finally creeps near their domains, will the constellations slip out of sight in the west.

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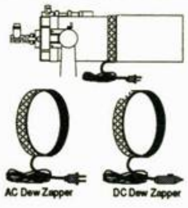

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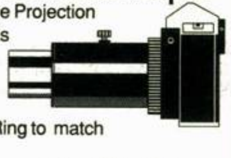

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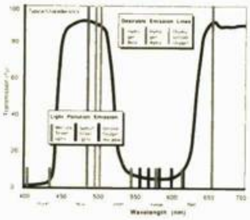

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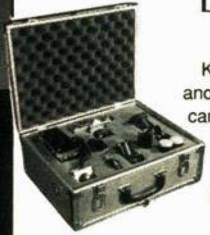

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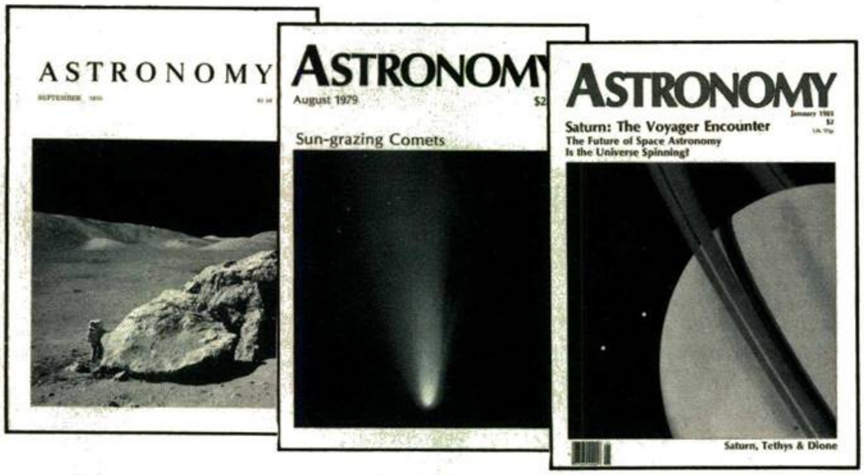
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STAYING UP NIGHTS

Astronomy clubs and star parties provide companionship, advice, and fun for summer observers

NATIONAL/INTERNATIONAL ORGANIZATIONS

American Association of Variable Star Observers. Birch Street, Cambridge, MA 02138. Janet Mattei, (617) 354-0484.
Guides observers in observing programs of variable stars, receives observations, computerizes, processes, and disseminates information. Customized observing kit for location, instruments, level of experience available. Two annual meetings.

Association of Lunar and Planetary Observers. P.O. Box 16131, San Francisco, CA 94116. Dr. John E. Westfall, (415) 566-5786. Members nationwide, observing manuals on solar system objects available at cost. 1987 convention with Astronomical League and Astronomical Society of the Pacific; A.L.P.O. will hold a paper session, workshop on observing techniques, and exhibit.

Asteroid Project, World Space Foundation, P.O. Box Y, Pasadena, CA 91030-1000. Jack Child, (818) 799-5135.
Volunteer and staff support to asteroid discovery observations at Palomar Mountain and for data reduction at the Jet Propulsion Laboratory, some support for follow-up observations by well-equipped amateur astronomers. *Visitors with interest or expertise in asteroid observing at meetings by appointment.*

Astronomical Society of the Pacific. 1290 24th Avenue, San Francisco, CA 94122.
International scientific and educational organization, membership open to everyone, "Astronomy as a Hobby" packet available. Recorded astronomy news hotline, (415) 661-0500.

International Occultation Timing Association. P.O. Box 7488, Silver Spring, MD 20901. David W. Dunham, (301) 585-0989.
Service organization: observing, recording and analyzing eclipses and occultations, annual formal meeting.

LOCAL GROUPS

ALABAMA

Birmingham

Birmingham Astronomical Society. 1425 22nd Street South, 35205. Emmie Longshore, (205) 933-8422.
Monthly group observing session or star party. Informal get-togethers with speakers, films. *Monthly program meetings fourth Tuesday.*

Tuscumbia

Muscle Shoals Astronomical Society, Inc. 302 N.E. Commons, 35674. Homer Russell, Jr., (205) 383-6717.
Observe lunar, planetary, and deep-sky objects. *Monthly meetings second Thursday.*

ARKANSAS

Ashdown

Ark-Tex Skywatchers. Route 2, Box 9, 71822. Walter Webb, (501) 898-3178.
Programs and public viewing nights, promote astronomy, educate public. *Monthly meetings third Saturday.*

CALIFORNIA

Altadena

Polaris Astronomical Society. 228 East Pentagon Street, 91001. Rick Shaffer, (818) 797-2845.
Monthly meetings fourth Wednesday 7:30 p.m.

Concord

Mount Diablo Astronomical Society. 4135 Pickwick Drive, 94521. Summer park programs, star parties. *Monthly park programs second Tuesday 7:30 p.m.*

Corona

Riverside Astronomical Society. 413 West Kendall, 91720. Tom Fangrow, (714) 735-2068. Meetings with guest speakers, monthly star parties, annual Riverside Telescope Makers Conference Memorial Day weekend. *Monthly meetings first Saturday.*

Fresno

Central Valley Astronomers. The Discovery Center, 1944 N. Winery Avenue, 93703. *Monthly meetings first Saturday 7:30 p.m.*

Hayward

AstroSoft. P.O. Box 4451, 94540-4451. Martin E. Morrison, (415) 278-8458.
Promotes the use of computers and computer software in the science of astronomy and related sciences for education; observational emphasis: planets and deep-sky objects with naked eye, binoculars, and telescopes. *Meetings irregular, visitors by special arrangement.*

Idyllwild

Idyll-Gazers Amateur Astronomy Club. P.O. Box K, 92349. Joe Neu, (714) 659-3562.
Star parties June 25-27, July 23-25, and August 20-22; lectures and panel discussions. *Monthly business meetings last Tuesday.*

Los Angeles

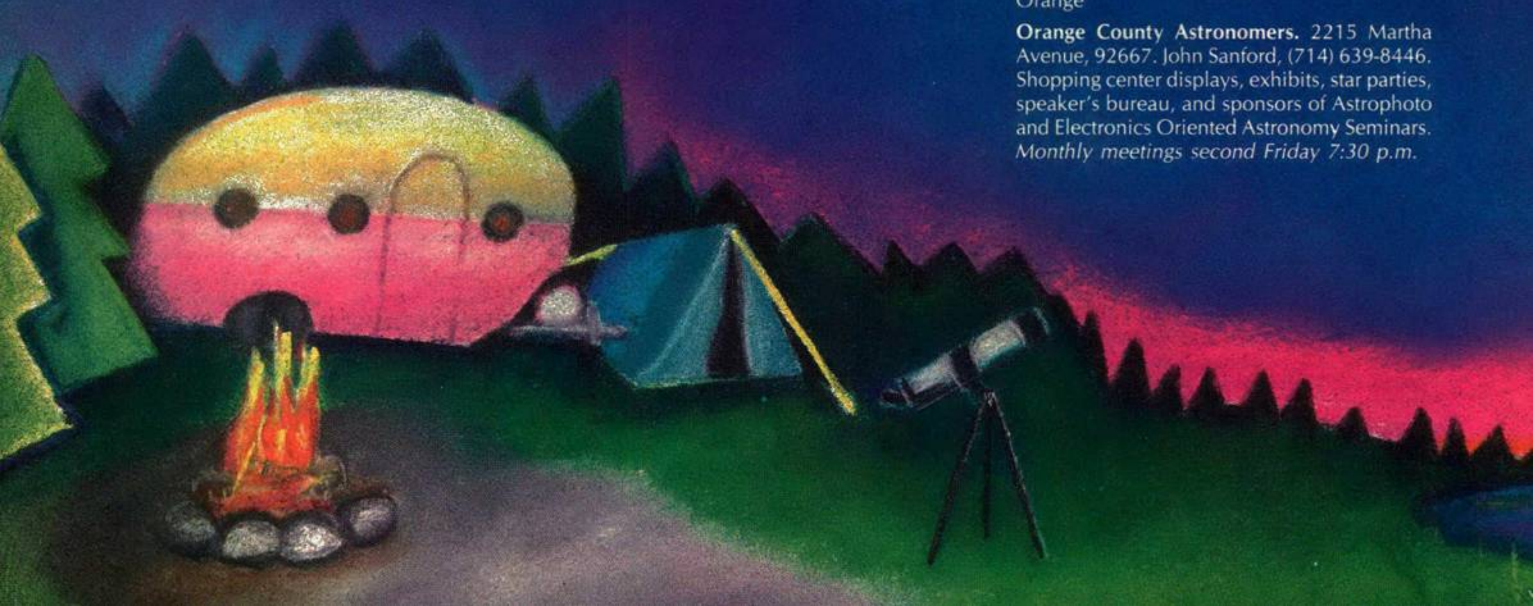
Los Angeles Astronomical Society. 2800 East Observatory Road, 90027. Tom Dorff, (213) 926-4071.
Works closely with Griffith Observatory for special events, Space Week star party; operates Monterey Park City Observatory.

Morago

Amateur Astronomers of Northern California. 731 Camino Ricardo, 94556. Don Stone, (415) 376-3007.
Umbrella group representing many astronomical societies in Northern California, coordinates star parties, sponsors yearly major convention; sponsors STARBQ hosted by the San Francisco Amateur Astronomers on Mount Tamapais in Marin County June 27, telescope judging event and star party at Fremont Peak State Park August 22.

Orange

Orange County Astronomers. 2215 Martha Avenue, 92667. John Sanford, (714) 639-8446. Shopping center displays, exhibits, star parties, speaker's bureau, and sponsors of Astrophoto and Electronics Oriented Astronomy Seminars. *Monthly meetings second Friday 7:30 p.m.*



San Bernardino

San Bernardino Valley Amateur Astronomers. 1345 Garner Avenue, 92411. David Garcia, (714) 884-0657.
Co-contributors to Riverside Telescope Makers Conference, monthly star parties; observational emphasis: constellations, deep-sky objects, and double stars. *Monthly meetings third Saturday 7:30 p.m.*

San Francisco

San Francisco Amateur Astronomers. Morrison Planetarium, California Academy of Sciences, 94118. William J. Cherrington, (415) 752-9420.
Lectures, slide shows, movies, astronomy presentations. *Monthly star parties May 30, June 27, July 25, and August 22. Monthly meetings third Monday 8 p.m.*

San Francisco Sidewalk Astronomers. 160 Baker Street, 94115. John Dobson, (415) 567-2063.
Dedicated to public service in astronomy, set up telescopes for public use, slide shows, astronomy and cosmology, telescope-making classes. *Monthly meetings third Monday 8 p.m. with San Francisco Amateur Astronomers.*

Emery Hildebrand

San Juan Bautista

Fremont Peak Observatory Association. Fremont Peak State Park, P.O. Box 1110, 95045. Denni Medlock, (415) 654-6796.
Public education, interpretive services in cooperation with the California State Parks System for the operation of observatory, lectures, slide shows, observing. *Observatory open to public on First Quarter and Third Quarter Moon Saturday nights.*

San Luis Obispo

Central Coast Astronomical Society. P.O. Box 1415, 93406. Lee Coombs, (805) 528-6682. *Monthly meetings fourth Thursday 7:30 p.m.; observing sessions Saturdays nearest New Moon.*

Simi Valley

Ventura County Astronomical Society. P.O. Box 982, 93062. Hal Jandorf, (805) 529-3984.
Programs on astrophotography, astrophysics, cosmology, telescope and equipment reviews, planetary and deep-sky observing hints; monthly star parties; summer weekend programs at Moorpark College Observatory with lectures and observing. *Monthly meetings third Friday 7:30 p.m.*

COLORADO

Denver

Denver Astronomical Society. P.O. Box 10814, 80210. Ivan Geisler, (303) 431-6218.
Telescope making, photography, and deep-sky emphasis; public nights Thursday. *Monthly meetings second and fourth Fridays.*

CONNECTICUT

Hartford

Astronomical Society of Greater Hartford. The Science Museum of Connecticut/Gengras Planetarium, 950 Trout Brook Drive 06119. *Monthly meetings third Wednesday September-June.*

DELAWARE

Greenville

Delaware Astronomical Society. Mount Cuba Astronomical Observatory, P.O. Box 3915, Hillside Mill Road, 19807.
Lectures, field trips. *Monthly meetings third Tuesday June-September 8 p.m.*

FLORIDA

Pensacola

Escambia Amateur Astronomer's Association. 6235 Omie Circle, 32504-7625. Dr. Wayne Wooten, (904) 476-5410 extension 1154; evenings (904) 477-8732.
Co-hosts Sky Interpretation Session with National Park Service: June 19, July 3, July 17, July 31, and August 14 at 8:30 p.m. *Monthly meetings June 12, July 10, and August 14 at 7 p.m.*

St. Petersburg

St. Petersburg Astronomy Club, Inc. 594 59th Street South, 33707. Daniel W. Bricker, (813) 343-1594.
Biannual regional star parties, monthly observing and programs; active telescope makers, astrophotographers, deep-sky emphasis. *Monthly meetings fourth Friday 8 p.m.*

HAWAII

Captain Cook

Mauna Kea Astronomical Society. RR1, Box 525, 96704. Howard Yamasaki, (808) 329-2353 (days), (808) 328-9201 (evenings). Lectures, guest speakers.

Honolulu

Hawaiian Astronomical Society. P.O. Box 17671, 96817. Ray Fabre, (808) 488-0375.
Monthly star party, public observing Friday-Saturday. *Meetings June 2, July 7, and August 4 at 7:30 p.m.; star parties June 27, July 25, and August 22 at 6:30 p.m.*

ILLINOIS

Barrington

Northwest Suburban Astronomers. 4960 Chambers Drive, 60010. Lance Worrell, (312) 956-6159.
Monthly star parties, solar observing, weekend campouts; general, deep-sky, and astrophotography emphasis. *Meetings June 12 9:30 p.m.; July and August to be announced.*

Chicago

Chicago Astronomical Society. P.O. Box 48504, 60648.

Glenview

Space Science Explorer Post #998. 910 Glenwood Lane, 60025. Gretchen Trinklein, (312) 998-1627.
Space science club for ages 14-21, astronomy, model rocketry, astrophotography, science fiction. *Wednesday meetings.*

Naperville

Naperville Astronomical Association. 910 Fairway, Apt. 203, 60540. Ray Bright, (312) 369-3533.
Speakers, star parties (May-September) Wednesday 8 p.m. *Monthly meetings first Tuesday 7:30 p.m.*

Normal

Twin City Amateur Astronomers. Illinois State University Planetarium, 61761-6901. *Monthly meetings third Saturday 7 p.m.*

Illustration by Jim Pogorzelski

Quincy

Quincy Astronomical Society. 1200 St. Charles Drive, 62301-7160. Kevin Clymer, (217) 224-9600 (day); (217) 222-6535 (night).
Monthly meetings third Friday 7:30 p.m.

Rock Island

Popular Astronomy Club, Inc. John Deere Planetarium, Augustana College, 61201. Paul R. Castle, (309) 786-6119.
Monthly meetings second Monday 7:30 p.m., Perseid shower meeting in August.

Rockford

Rockford Amateur Astronomers, Inc. 6804 Alvina Road, 61103. Barry or Carol Bearman, (815) 962-6540.
Observational emphasis: deep-sky, planetary, and variable star observing. *Viewing every second and fourth Saturday 7:30-11 p.m.; monthly meeting third Wednesday 7:30 p.m.*

IOWA

Cedar Rapids

Cedar Amateur Astronomers. Ambroz Art Center, 52321. Doug McCloy, (319) 485-3298.
Monthly observing sessions, stellar photometry, asteroid plotting, planetary observing, and photography. *Monthly meetings first Wednesday.*

Davenport

Quad Cities Astronomical Society. P.O. Box 3706, 52808. Wayne Jens, (319) 326-4995.
Star parties: June 19, July 24-25, August 21; deep-sky emphasis. *Monthly meetings third Monday 7:30 p.m. (except July and August).*

KENTUCKY

Louisville

Louisville Astronomical Society. Museum of History and Science, 727 West Main Street, 40402. Alan Goldstein, (502) 589-4584.
Guest speakers, slide programs, deep-sky and planetary observing, astrophotography. *Meetings June 5, July 10, and August 7*

LOUISIANA

Abbeville

Astronomical Society of Acadiana. 805 South Guegnon, 70510. Dave Thomas, (318) 837-2871.
Lectures, deep-sky and planetary observing. *Monthly meetings last Thursday 7 p.m.*

Baton Rouge

Baton Rouge Astronomical Society, Inc. 12635 Parnell Avenue, 70815. Wally Pursell, (504) 275-2395.
Co-founder of Deep South Regional StarGaze, star parties. *Monthly meetings first Monday 7 p.m.*

New Orleans

Pontchartrain Astronomy Society, Inc. 2754 Holiday Drive, 70114. Michael W. Bourque, (504) 393-9402.
Monthly star parties, field trips to nearby astronomical facilities, lectures to education and civic organizations, co-founder of Deep South Regional Star Gaze. *Monthly meetings third Friday 8 p.m.*

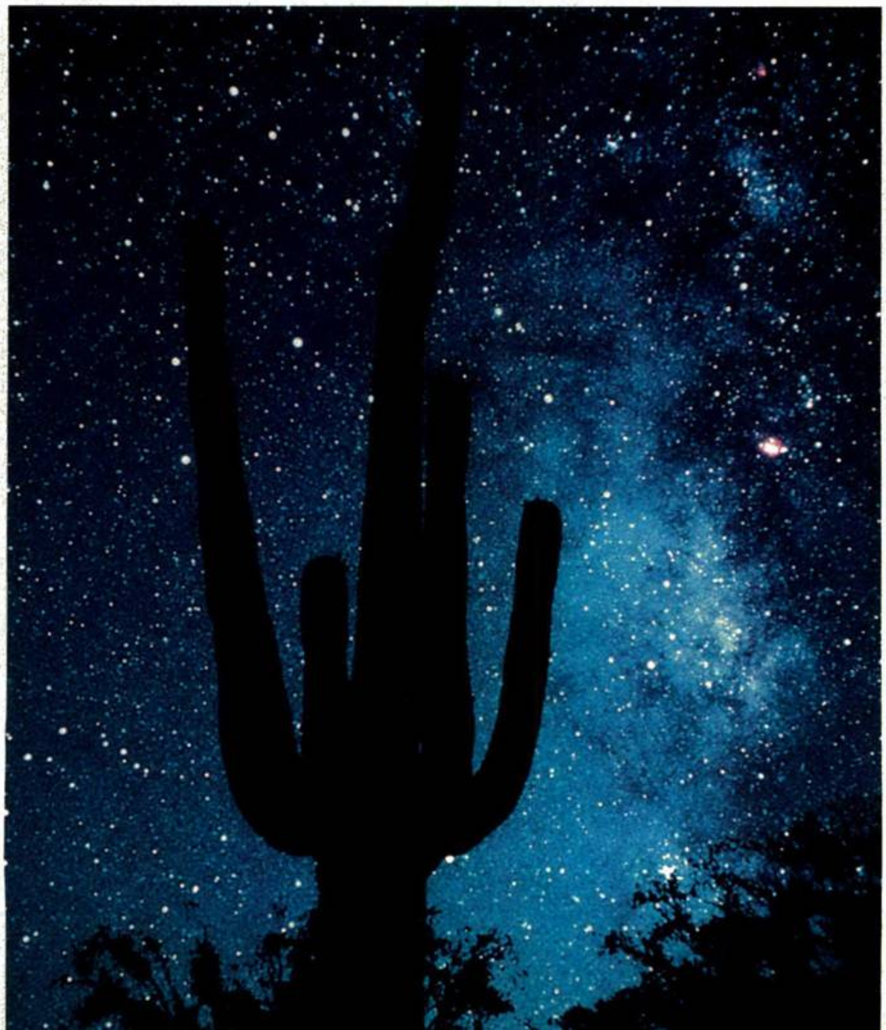


Photo composite by Frank Zullo

MAINE

Eliot

Astronomical Society of Northern New England. 80 Goodwin Road, 03903. (207) 439-4474.
Constellation viewing, scientific education. *Monthly meetings first Friday 7:30 p.m.*

MARYLAND

Baltimore

Baltimore Astronomical Society. Davis Planetarium, Maryland Academy of Sciences, 601 Light Street, 21230. (301) 685-5225.

MASSACHUSETTS

West Springfield

Springfield Stars Club. 107 Lower Beverly Hills, 01089. John E. Welch, (413) 734-9197. Speakers, slides, visits to nearby college observatory, observing.

MICHIGAN

Detroit

Detroit Astronomical Society. Jack Brisbane, (313) 837-0130.
Astrophotography, astronomical computer programs, telescope assembly, mirror grinding, polishing, and testing. *Meetings Fridays 8 p.m.*

Grand Rapids

Grand Rapids Amateur Astronomical Association. 3308 Kissing Rock Road S.E., near Lowell. (616) 456-3985.
Monthly meetings second Saturday and last Friday April-October 8:30-11 p.m.

Muskegon

Muskegon Astronomical Society. P.O. Box 363, 49443. Dale Johnson, (616) 798-7680.
Multiple star, planetary, and deep-sky observing; public viewing June 26-27, August 28-29. *Monthly meetings second Tuesday 7:30 p.m.*

MINNESOTA

Duluth

Arrowhead Astronomical Society. University of Minnesota-Duluth, 55812.
Monthly meetings third Wednesday.

Moorhead

Moorhead-Fargo Astronomical Society. Department of Physics, Concordia College, 56560.
Talks, special trips. *Monthly meetings second Monday 7:30 p.m.*

St. Paul

Minnesota Astronomical Society. 30 East 10th Street, 55101. Max Radloff, (612) 451-7686. Star parties, teach field course in astronomy through the University of Minnesota. *Monthly meetings first Tuesday 7:30; star parties (tentative) June 26, July 24, August 21, star party for the Perseids.*

MISSISSIPPI

Jackson

Jackson Astronomical Association. 6207 Winthrop Circle, 39206. Walter Rebmann, (601) 982-2317.
Messier, Herschel, and asteroid searches, astrophotography, meteor showers, graze and occultation recordings, light pollution prevention. *Monthly meetings first Friday 7:30 p.m.*

MISSOURI

Blue Springs

Astronomical Society of Kansas City. P.O. Box 400, 64015. (816) 432-9077.
Star parties, hosts the Midstate Convention of the Astronomical League on July 24, 25, and 26. *Monthly meetings fourth Saturday 7:30 p.m.*

St. Peters

St. Louis Astronomical Society. 310 Westminster, 63376. Cecelia Brown, (314) 278-1191. Observing sessions, Messier program group, Space Week activities at St. Louis Science Center July 16-24. *Observing sessions June 27 and July 25 at 9 p.m., August 22 at 8 p.m.*

Winfield

Rural Astronomers of Missouri. RR 1, Box 501, 63389. John Sgouros, (314) 668-8574.
Observing, occasional star parties.

NEBRASKA

Lincoln

Prairie Astronomy Club, Inc. P.O. Box 80553, 68501. Lee Thomas, (402) 483-5639.
Field trips, public observing every Saturday night, star parties. *Monthly meetings last Tuesday 7:30 p.m.*

Omaha

Omaha Astronomical Society. 3390 South 130th, 68144. Joyce Zalud.
Field trips to observing and educational sites.

NEVADA

Las Vegas

Las Vegas Astronomical Society. Clark County Community College Planetarium, 3200 East Cheyenne Avenue, 89030. John Kalas, (702) 456-2659.
Two observing sessions per month, committed to the astronomy education of members and general public. *Monthly meetings first Tuesday 7:30 p.m.*

Reno

Astronomical Society of Nevada. 825 Wilkinson Avenue, 89502. Garth Elliott, (702) 673-3421.
Monthly star parties, special interest group devoted to astrophotography. *Meetings June 12, July 10, August 7 at 7:30 p.m.*

An Historic Conjunction of Astronomical Groups

This summer a unique astronomical event will occur: the joint meeting of the Astronomical League, the Astronomical Society of the Pacific, the Western Amateur Astronomers, the Association of Lunar and Planetary Observers, the International Amateur-Professional Photoelectric Photometry group, and the International Occultation Timing Association on July 11-17 at Pomona College in southern California. This is the first time all of these major amateur and professional groups have met together.

Activities throughout the week will include invited talks on amateur astronomy, a workshop on teaching astronomy, and a scientific symposium for professional astronomers.

Nontechnical papers, seminars, and workshops will focus on the fun of amateur astronomy. Topics include:

- Halley's Comet by Stephen Edberg of the Jet Propulsion Laboratory and coordinator of the International Halley Watch.
- Joys of Amateur Astronomy by David Levy, comet discoverer.
- Exploding Stars by Virginia Trimble of the University of California and the University of Maryland.
- Quasars by Alan Stockton of the University of Hawaii.
- Collecting Astronomical Books as a Hobby by Donald Yeomans of JPL.
- Searching for Supernovae: The Role of Amateurs by Stephen Lucas, who started a group of amateur supernovae hunters.
- Building Telescopes by Richard Berry, editor of ASTRONOMY.

There will also be a panel discussion by amateurs who have discovered comets, and sessions on computers in amateur astronomy, light pollution, astrophotography, planetary observing, and an introduction to the constellations.

A special seminar for teachers, "The Universe in the Classroom: A Workshop for Teachers," is also part of the meeting. It is designed for teachers of astronomy in grades 3-12. The workshop is offered for graduate credit and includes guidance for selecting telescopes and computer software for classroom use, plus hands-on sessions about classroom activities and resources.

"Cool Stars and the Structure of Galaxies" will be the topic of a scientific symposium for professional astronomers. Papers will cover infrared spectroscopic, optical, ultraviolet, and x-ray observations of cool stars, the galactic bulge, the Oort limit, and the size of the Galaxy.

The Astronomical Society of the Pacific's annual Bart Bok Memorial Lecture will be given this year by Kip Thorne of the California Institute of Technology and is titled "Black Holes, White Holes, Worm Holes, and Tunnels through Hyperspace."

Lectures throughout the week will include "The Hubble Constant and the Expansion of the Universe: Fifty Years of Controversy" by Allan Sandage of the Carnegie Observatories on leave to Johns Hopkins University, "From Planck Time to the Modern Universe: How Can It Be That We Exist" by William Kaufmann of San Diego State University, and "Searching for Extraterrestrial Life: 1600-1987" by Frank Drake of the University of California at Santa Cruz. Tours of local observatories and the Jet Propulsion Laboratory are also planned.

All events are open to the public, though preregistration is required. For a schedule of events, write to : A.S.P., Summer Meeting Department, 1290 24th Avenue, San Francisco, CA 94122. Discount accommodation and transportation rates are available for conference participants. *Kristine R. Majdacic.*

NEW HAMPSHIRE

Keene

Keene Amateur Astronomers, Inc. 12 Gardner Street 03431. Philip N. Atwood, (603) 352-5058.
Monthly meetings second Tuesday.

NEW JERSEY

Clifton

North Jersey Astronomical Group. P.O. Box 4021, Allwood Station, 07012. Rifle Camp Park Nature Center, (201) 523-0024.
Telescope making, astrophotography, dark room, astronomy classes. *Monthly meetings second Wednesday 8 p.m.; public nights, Friday (except July 3, July 24, and July 31) sunset-10 p.m.*

Cranford

Amateur Astronomers, Inc. W. M. Sperry Observatory, 1033 Springfield Avenue, 07016. George Chaplenko, (201) 549-0615.
Qualified observers course, adult astronomy classes, free lectures to civic organizations. *Public viewing Fridays 7:30-10:30 p.m.; monthly meetings 8 p.m. September-May.*

High Bridge

New Jersey Astronomical Association. Voorhees State Park, P.O. Box 214, 08829. Ben Cavotta, (215) 253-7294.
Observatory open house July 18; general viewing. *Monthly meetings fourth Saturday.*

Toms River

ASTRA. Novins Planetarium, Ocean County College 08754-2001.
Presentations, films, videos, workshops, star parties. *Monthly meetings second Friday 8 p.m. (except August).*

NEW MEXICO

Alamogordo

Alamogordo Amateur Astronomers. 1210 Filipino, 88310. Paula Hamilton, (505) 434-0115. Observatory outings, star parties. *Monthly meetings second Tuesday 7 p.m.*

Albuquerque

Albuquerque Astronomers. 14328 Mocho NE, 87123. Bruce Levin, (505) 299-0891.
Field trips, deep-sky, planetary, and general observing, astrophotography, junior group. *Monthly meetings.*

NEW YORK

Buffalo

Buffalo Astronomical Association, Inc. Buffalo Museum of Science, Humboldt Parkway, 14211. Doris Koestler, (716) 683-2970.

New York

Amateur Astronomers Association of New York City. 1010 Park Avenue, 10028. John Marshall, (212) 535-2922.
Observing sessions, lectures, classes, constellation study, telescope making, trips to observatories, slide shows.

Pearl River

Rockland Astronomy Club. 110 Pascack Road, 10965. Allan Green, (914) 735-4163.
Observing sessions, trips.

Saranac Lake

Tri-Lakes Astronomical Society. Post Office Box 806, 12983. Dan Ferguson, (518) 891-0339.
Presentations, demonstrations, workshops, films. Observational emphasis: general astronomy and astrophotography. *Monthly meetings second Thursday 7:30 p.m.*

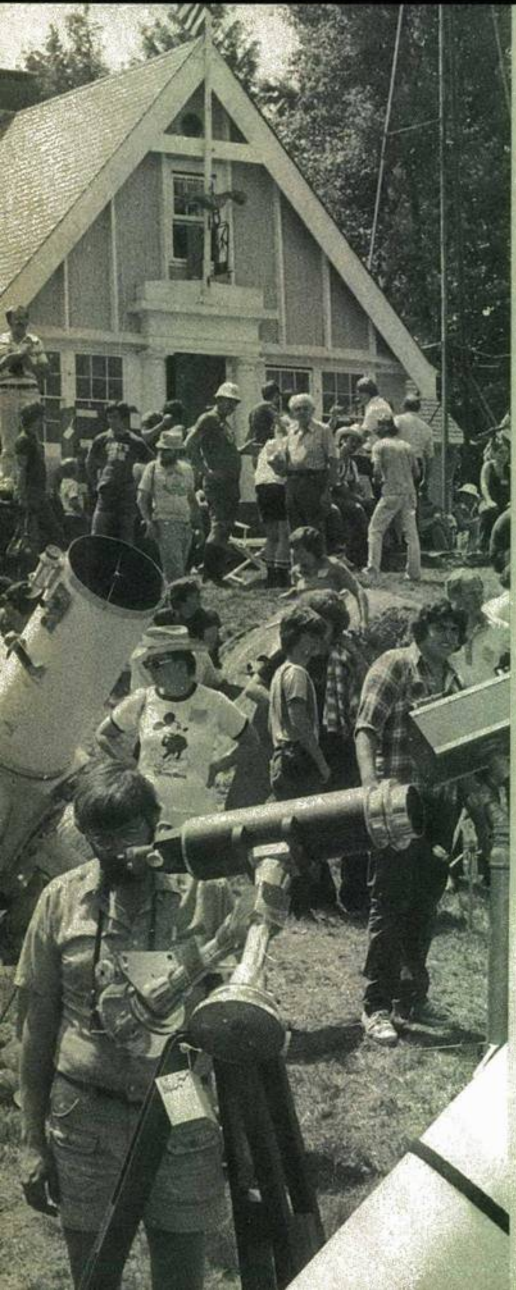
Schenectady

Albany Area Amateur Astronomers, Inc. 1529 Valencia Road, 12309. Bob Mulford, (518) 374-8744.
Star parties: June 20 and 27, 9 p.m.; July 18, 9 p.m.; August 1, 22, and 29, 9 p.m.; deep-sky, binocular, and planetary observing. *Monthly meetings third Tuesday.*

Syracuse

Syracuse Astronomical Society, Inc. 1115 East Colvin Street, 12310. Denise Sabatini, (315) 458-1454.
Public observing sessions: June 5, 6, 19, 20, 21,

SUMMER ASTROCALENDAR



May 8-August 16
"25 Years of Space Photography" (140 photographs taken by unmanned spacecraft; organized by the Baxter Art Gallery at the California Institute of Technology and sponsored by IBM), George Eastman House, Rochester, New York. Contact: Robert A. Sobieszek, 900 East Avenue, Rochester, NY 14607. Phone: (716) 271-3361.

May 22-25
19th Annual Riverside Telescope Makers Conference (sponsored by the Riverside Astronomical Society and the San Bernardino Valley Astronomers), Camp Oakes, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92503. Phone: (714) 689-6893.

May 25-30
Texas Star Party, Fort Davis, Texas. Contact: T.S.P. Registrar, 128 North Commerce, Burleson, TX 76028.

May 30
Hidden Hollow '87 Conference and Star Party (sponsored by the Richland Astronomical Society and the Ohio Turnpike Organization), Mansfield, Ohio. Contact: Hidden Hollow '87, The Friendly House, 380 North Mulberry Street, Mansfield, OH 44902.

June 2-July 3
Standing Stones on the Isle of Mull (archeoastronomy expedition to study prehistoric stone circles in Scotland; a second team will be in Scotland July 6-17). Contact: Earthwatch, 680 Mount Auburn Street, Box 403N, Watertown, MA 02272. Phone: (617) 926-8200.

June 6
Dedication of Arkansas' Largest Free Observatory (speeches, observing, fly-over), Donald C. Coleman Observatory, south of Fort Smith, Arkansas. Contact: Ross Kennedy, 3805 McArthur Drive, Fort Smith, AR 72904.

June 6-7
Space Expo '87 (sponsored by the Cradle of Aviation Museum and the Space Frontiers Society of Long Island), Garden City, New York. Phone: (516) 222-1191.

June 8-12
Southeast Planetarium Association Meeting, Brevard Community College, Cocoa, Florida. Contact: Mike Hutton, Brevard Community College, 1519 Clearlake Road, Cocoa, FL 32922.

June 12-13
17th Annual Apollo Rendezvous and Telescope Fair (sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History), Dayton, Ohio. Contact: Robert Sponseller, 2629 Ridge Avenue, Dayton, OH 45414. Phone: (513) 879-5645.

June 14-18
Joint Meeting of the American Astronomical Society and the Canadian Astronomical Society (professional meeting hosted by the University of British Columbia), Vancouver, British Columbia, Canada. Contact: AAS/CAS Meeting, 801-750 Jervis Street, Vancouver, British Columbia, Canada V6E 2A9.

June 20
"The Solstice Is Coming" (solar energy demonstrations, planetarium programs), Rotary Planetarium and Discovery Center, Syracuse, New York. Contact: Stephen Karon, Rotary Planetarium and Discovery Center, 321 South Clinton Street, Syracuse, NY 13202. Phone: (315) 425-9068.

June 22-26
Dark Sky '87 — Visual Astronomy Conference, St. John's College, Santa Fe, New Mexico. Contact: Dark Sky '87, 535 Cordoba Road, Suite 130, Santa Fe, NM 87501. Phone: 1-800-DARKSKY.

June 22-26
Observational Astronomy Workshop for Teachers (techniques of observational astronomy, including the use of telescopes, astrophotography, sponsored by Ball State University), Muncie, Indiana. Contact: David R. Ober, Summer Programs, Department of Physics and Astronomy, Ball State University, Muncie, IN 47306. Phone: (317) 285-8860.

June 22-July 31
Utah State University's Ralph M. Johnson Distinguished Guest Lecturer Series (astronomy and cosmology featuring Virginia Trimble, Michael Turner, Bradford A. Smith, John Huchra, and Gary Steigman), Utah State University, Logan, Utah. Contact: Professor Grant Gill Smith, Department of Chemistry and Biochemistry, Utah State University, Logan, UT 84322-0300. Phone: (801) 750-1624.

26, 27, 28; July 3, 4, 17, 18, 19; August 12, 21, 22, 23, 28, 29, 30.

NORTH CAROLINA

Castle Hayne

Cape Fear Astronomy Club. 110 Linville Drive, 28429. Deborah Petty, (919) 675-2952.
Mall exhibits, meteor shower viewing, field trips. *Monthly meetings first Sunday 7:30.*

Fayetteville

Astronomy Club of Cumberland County. 2308 Colgate Drive, 28304. Allen Faircloth, (919) 485-8515.
Observing sessions. *Monthly meetings second Wednesday 7:30 p.m.*

Granite Falls

Catawba Valley Astronomy Club. 12 East Street, 28630. Greg Kirby, (704) 396-7656.
Stargazing, field trips, Astronomy Day activities, host annual Blue Ridge Parkway Regional Stargaze, deep-sky and astrophotography interest. *Monthly meetings second Thursday 7:30 p.m.*

Salisbury

Astronomical Society of Rowan County. Margaret C. Woodson Planetarium, 1636 Parkview Circle, 28144. Ellen Trexler, (704) 636-3462.
Monthly meetings June 17 and July 15; all-night star party June 27; star party and cookout July 18.

OHIO

Akron

Astronomy Club of Akron. 5070 Manchester Road, 44319. Philip Hegenderfer, (216) 644-0230.
Monthly meetings, school presentations, summer star parties, telescope-making classes, community fund-raising projects.

June 27
Arkansas Star Party (sponsored by the Ark/Okla Astronomical Society), Douglas C. Coleman Memorial Observatory, Sugarloaf Mountain, Arkansas. Contact: Larry Kennedy, Route 3 Box 421-W, Pocola, OK 74902. Phone: (918) 436-2204 evenings.

June 27
31st Ohio Turnpike Astronomers Association Annual Convention (sponsored by the Cuyahoga Astronomical Association of Cleveland), Hiram College, Hiram, Ohio. Contact: Paul Leopold, P.O. Box 29089, Parma, OH 44129. Phone: (216) 734-9588.

July 2-5
Yellowstone's Night Skies (outdoor observing techniques for telling time by the Sun and Moon, predicting eclipses, and tracking planets), Yellowstone National Park, Wyoming. Advanced registration required. Contact: Yellowstone Institute, P.O. Box 117, Yellowstone National Park, WY 82190. Phone: (307) 344-7381 extension 2384.

July 8-11
5th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun (review papers and discussions sponsored by the University of Colorado), Boulder, Colorado. Contact: 5th Cool Stars Workshop, CASA, Campus Box 391, University of Colorado, Boulder, CO 80309-0391.

July 11-12
National Workshop on Teaching Astronomy for Teachers (graduate credit available, offered during the Astronomical Society of Pacific annual meeting), Pomona College, Claremont, California. Contact: Andrew Fraknoi, Summer Workshop, A.S.P., 1290 24th Avenue, San Francisco, CA 94122. Phone: (415) 661-8660.

July 11-17
Joint Conference of the Astronomical Society of the Pacific, the Astronomical League, the Western Amateur Astronomers, and other national associations, Pomona College, Claremont, California. Contact: Andrew Fraknoi, Summer Meeting, A.S.P., 1290 24th Avenue, San Francisco, CA 94122. Phone: (415) 661-8660.

July 13-30
Astronomy Seminar for Science Teachers (three-week presentation on astronomical topics; lectures, observing, demonstrations, and discussions for teachers of science, grades 7-12.) Contact: Director of Summer School, Whitney Hall, St. Cloud State University, St. Cloud, MN 56301.

July 16-24
Space Week '87 ("Space: In Service of Man"). Contact: Jim Harris, Florida Space Society, P.O. Box #291, Sharpes, FL 32959. Phone (message only): (305) 455-3390.

July 16-24
Space Week (films, telescope displays, solar observatory, evening star party; sponsored by Noble Planetarium), Fort Worth Museum of Science and History, Fort Worth, Texas. Contact: Michael P. Walker, Noble Planetarium, 1501 Montgomery Street, Fort Worth, TX 76107. Phone: (817) 732-1631.

July 16-24
Space Week (special programs, workshops, field trips), Lafayette Natural History Museum and Planetarium, Lafayette, Louisiana. Contact: Donna Savoie, Lafayette Natural History Museum and Planetarium, 637 Girard Park Drive, Lafayette, LA 70503. Phone: (318) 261-8350.

July 17-18
5th Annual Burke Lake Telescope Meet, Burke, Virginia. Contact: John S. Huggins, 5608 Flag Run Drive, Springfield, VA 22151.

July 18-22
Case for Mars III: Strategies for Exploration (papers, workshops, panel discussions on Martian exploration), Boulder, Colorado. Contact: Case for Mars III, P.O. Box 4877, Boulder, CO 80306. Phone: (303) 494-8144.

July 24-25
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Road, Sudbury, MA 01776.

July 24-26
Midstate Convention of the Astronomical League (sponsored by the Astronomical Society of Kansas City), Bluesprings, Missouri. Contact: Astronomical Society of Kansas City, P.O. Box 400, Blue Springs, MO 64015.

July 24-26
Alberta Star Party (sponsored by the Royal Astronomical Society of Canada, Calgary Center), Chain Lakes Provincial Park. Contact: Simon Hum, Quasar Optics, 7220 A, Fairmount Drive S.E., Calgary, Alberta, T2H 0X7. Phone: (403) 255-7633.

August 2-4
Star Trails West (study early exploration of the West and astronomy for navigation and map making, Native American astronomy, history of early American astronomy), Yellowstone National Park, Wyoming. Advanced registration required. Contact: Yellowstone Institute, P.O. Box 117, Yellowstone National Park, WY 82190. Phone: (307) 344-7381 extension 2384.

August 3-6
Observational Astronomy Workshop (lectures and observing, sponsored by St. Cloud University), St. Cloud, Minnesota. Contact: the Director of Summer School, Whitney Hall, St. Cloud University, St. Cloud, MN 56301.

August 8
Annual OTAA Convention (sponsored by the Astronomy Club of Akron and the University of Akron), Auburn Science Center, University of Akron, Akron, Ohio. Contact: Lauri Kunkel, 131 Oakdale Avenue, Akron, OH 44302. Phone: (216) 762-5748.

August 14-16
17th Annual Niagara Frontier Council of Amateur Astronomical Association Summer Seminar (sponsored by the Syracuse Astronomical Society, Inc.), Vesper, New York. Contact: Denise Sabatini, 342-1/2 Chestnut Street, North Syracuse, NY 13212. Phone: (315) 458-1454 weekends and evenings.

August 20-24
4th Annual Mount Kobau Star Party (observing, telescope-making and astrophotography contests, speakers), Okanagan Valley, British Columbia, Canada. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T-1P4.

August 21-22
STARFEST '87 (6th annual observing convention sponsored by the North York Astronomical Association), River Place Campground, eight miles north of Mount Forest, Ontario. Contact: STARFEST '87, Andreas Gada, 145 St. George Street #701, Toronto, Ontario M5R 2M1.

August 21-23
4th Annual Mountain Astronomers Rendezvous and Star Party (sponsored by the Denver Astronomical Society and the Southern Colorado Astronomical Society), Royal Gorge Park, Canyon City, Colorado. Contact: Stefan C. Perrine, 7510 King Street, Westminster, CO 80030.

August 21-23
5th Connecticut River Valley Astronomers' Conjunction (three-day weekend of Milky Way viewing, lectures, camping), Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Road, Springfield, MA 01118.

Summer's 'Big Three' Star Parties

Every summer many amateur astronomers go on a pilgrimage to one of the "big three" star parties: the Riverside Telescope Makers Conference, Stellafane, and the Texas Star Party. Star parties offer opportunities to look at telescopes, exchange ideas and tips, attend talks by featured speakers, swap equipment, and, of course, to observe under dark skies. Each star party also offers very rugged accommodations —primitive bunkhouses and camping.

The three-day Riverside Telescope Makers Conference at Camp Oakes near Big Bear in southern California attracts roughly 1,500 observers and telescope makers every Memorial Day weekend. Riverside is a relatively new star party: this summer's event on May 22-25 is only the nineteenth. Telescope builders bring their latest creations and exchange ideas and designs; commercial exhibitors proudly display their newest wares and offer factory seconds for sale. Examining telescopes, observing, and talking to other amateurs are the main activities.

Stellafane in Springfield, Vermont, is steeped in tradition: it has been held since the 1930s. Two thousand people come each year to the crowded, one and a half day event on top of Breezy Hill with its little pink house to see the telescopes, eat the Green Mountain corn, meet with old friends, observe the night sky, and listen to the talks. This year Stellafane takes place July 24-25 when the Moon is New. Unlike Riverside, Stellafane does not encourage commercial exhibitors.

The Texas Star Party, held on the Prude Ranch in Fort Davis, Texas, is small, cozy, and dedicated to deep-sky observing. The setting of the party in the Davis Mountains of west Texas boasts some of the darkest skies of any American star party. About five hundred people — both advanced and beginning amateurs — attend each year primarily to observe. A slate of speakers is planned as well as tours to nearby McDonald Observatory. Swap meets and giveaways also take place. This year the event is scheduled for May 25-30.

These three star parties are the most famous, but they're not the only ones taking place this summer. Many amateur astronomy groups regularly hold star parties throughout the year, including Astrofest in September, which is sponsored by the Chicago Astronomical Society, and the Mount Kobau Star Party in August, which is held in Okanagan Valley, British Columbia.

See the Summer AstroCalendar on page 68 for other activities. *Kristine R. Majdacic.*

Chagrin Falls

Chagrin Valley Astronomical Society. P.O. Box 11, 44024. Kim Aebi, (216) 834-1506.
Public nights at club observatory, interest in photography, Comet Halley, and variable stars; annual star party August 22. *Monthly meetings first Sunday.*

Dayton

Miami Valley Astronomical Society. 2629 Ridge Avenue, 45414. Wade E. Allen, (513) 275-7431.
Public stargazes, classes, junior observing, deep-sky observing, astrophotography. *Monthly meetings second Friday 7:30 p.m.*

Parma

Cuyahoga Astronomical Association. P.O. Box 29089, 44129. Dawn Jenkins, (216) 521-5115.
Public programs. *Monthly meetings second Monday.*

OKLAHOMA

Pocola

Arkansas/Oklahoma Astronomical Society. Route 3, Box 421-W, 74902. Larry Kennedy, (918) 436-2204.
Guest speakers, slide shows, movies, workshops; telescopes available for loan. Building the largest observatory in Arkansas, will open in early June. *Monthly meetings third Saturday 7 p.m.*

OREGON

Eugene

Eugene Astronomical Society. Lane ESD Planetarium. P.O. Box 2680, 97402. Mel Bartels, (503) 741-0501.
Public star parties, classes, meetings. *Classes and meetings first Monday 7:30 p.m.*

Portland

OMSI Astronomers. Oregon Museum of Science and Industry, 4015 S.W. Canyon Road, 97221.
Star parties, observing, assist with planetarium displays. *Monthly meetings fourth Wednesday 7:30 p.m.*

Portland Astronomical Society. 1990 S.E. Mulberry Avenue, 97214. Larry Mahon.
Public displays, star parties. *Monthly meetings first Wednesday 8 p.m.*

Veronia

Northwest Astronomy Group. 55371 McDonald Road, 97064. Sandy Mikalow.

PENNSYLVANIA

Allentown

Lehigh Valley Amateur Astronomical Society, Inc. 755 East Rock Road, 18103. Rae Klahr, (215) 797-7430.
Planetarium programs, telescope-making classes, computer terminal-astrophotography, photometry program. *Monthly meetings second Sunday.*

Clarks Summit

Lackawanna Astronomical Society. 1112 Fairview Road, 18411. John D. Sabia, (717) 586-0789.
Lecture series (July), observing. *Monthly meeting first Tuesday.*

Kane

Sir Isaac Newton Astronomical Society. Box 591, 16735. William Bloom, (814) 837-6137.
Campout and star party June 5-7. *Monthly business meetings and program Wednesday closest to New Moon 7:30 p.m.*

Lewisburg

Astronomical Society of Harrisburg. P.O. Box 356, 17339. (717) 938-6041.
Courses for members and public, public observing Sunday at dusk (June, July, and August), occultation expeditions for IOTA, astrophotography, general observing. *Monthly meetings second Monday 8 p.m.*

New Kensington

Kiski Astronomers. 2 Aluminum City Terrace, 15068. Dennis Sopchack, (412) 337-0509.
Informal star parties, observing.

Philadelphia

Rittenhouse Astronomical Society. P.O. Box 12531, 19131. Dr. Milt Friedman, (215) 886-3466.
Lectures, field trips, special public events, astronomical education. *Monthly meetings first Friday 8 p.m. October-June.*

TENNESSEE

Knoxville

Smoky Mountain Astronomical Society. P.O. Box 6204, 37914-0204. Rita Fairman, (615) 637-1121.
Star parties. *Monthly meetings second Friday 8 p.m.*

Tullahoma

Middle Tennessee Astronomical Society. 113 Crestwood, 37388. Martin Nelius, (615) 455-5132.

TEXAS

Arlington

Fort Worth Astronomical Society. 1519 San Francisco Court #202, 76012. Kaye Hutchins, (817) 860-6858.
Public star parties, observing. *Monthly meetings Friday nearest New Moon dark to dawn.*

Corpus Christi

Corpus Christi Astronomical Society. 3814 Marion Street, 78415. Gary Mayer, (512) 852-7643.
Observing on clear Saturday nights.

Fort Worth

Texas Observers. Fort Worth Museum of Science and History, 1501 Montgomery Street, 76107.
Programs, star parties. *Monthly meetings fourth Saturday 1 p.m.*

Houston

Houston Astronomical Society. 8522 Bluegate Drive, 77025. Lee Cain, (713) 933-1289.
Guest speakers, slide shows, novice education programs, special interest programs, interests in astrophotography, occultations/grazes, deep-sky observing; field trips to observatory site June 27, July 25, and August 22; observatory open house June 20, July 18, and August 15, sunset-midnight. *Monthly meetings June 5, July 3, and August 7 8 p.m.*

Lubbock

South Plains Astronomy Club. 1920 46th Street, 79412-2214. Wayne Lewis, (806) 763-6800.
Group observing sessions, public star parties, programs; astrophotography, films, laser disc presentations. Emphasis: solar activity, Jovian satellite activity, deep-sky objects. *Monthly meetings third Thursday 7 p.m.*

UTAH

Roy

Ogden Astronomical Society. 2336 West 5650 South, 84067. Robert L. Tillotson, (801) 773-8106.
Talks, lectures, star parties, interest in observing, astrophotography, timing events, telescope making. *Monthly meetings 7:30 p.m.*

VERMONT

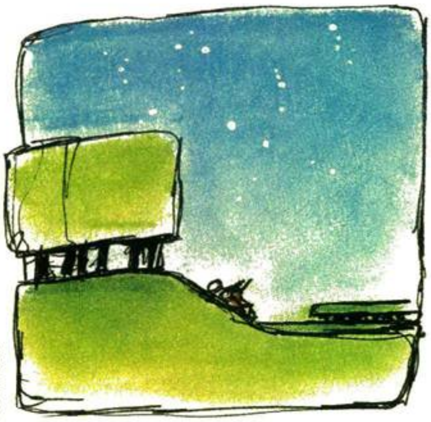
Essex Junction

Vermont Astronomical Society. 115 Sherwood Square, 05452. (802) 878-3459.
Deep-sky observing, astrophotography, amateur research in variable stars, sweeping for comets, minor planets, planetary, solar, lunar observing, and telescope making. *Monthly meetings first Monday 7:30 p.m.*

VIRGINIA

Harrisonburg

Shenandoah Valley Astronomy Club. Harrisonburg Department of Parks and Recreation. Lakey Logan, (703) 433-9168.



Tom Hunt

Springfield

Northern Virginia Astronomy Club. 5608 Flag Run Drive, 22151. John Scott Huggins, (703) 644-4331.
Public observing twice yearly, trips to local observatories, quarterly meetings, two night observing sessions per month. Burke Lake Telescope Meet (July).

Virginia Beach

Back Bay Amateur Astronomers. Glen Howell, (804) 485-4242.
Monthly meetings second Friday 8 p.m.

WASHINGTON

Centralia

Southwest Washington Astronomical Society. 2421 Leisure Lane, 98531. Carl M. Newton, (206) 736-6144.
Monthly meetings, star parties, mall and fair displays, slide shows.

Mead

Spokane Astronomical Society. P.O. Box 404, 99021. Thom Jenkins, (509) 535-0499.
Presentations, guest speakers. *Monthly meetings 7:30 p.m.*

WISCONSIN

Janesville

Rock Valley Astronomical Society. P.O. Box 1362, 53545. Douglas A. Thomson.
Deep-sky and planetary observing. *Monthly meetings first Tuesday 7 p.m., observing night Thursday nearest New Moon.*

Madison

Madison Astronomical Society, Inc. 205 Cameo Lane, 53714-2514. David D. Weier, (608) 241-1444.
Sponsors an Astronomy Explorer Scout Post for members 14-21, lectures, presentations. Interests in astrophotography and variable star observing, intermediate verifier for the Sunsearch Supernova Search Network, affiliated with the A.A.V.S.O., star parties. *Monthly meetings second Friday 7:30 p.m.*

Milwaukee

Milwaukee Astronomical Society. 188th and Observatory Road, New Berlin. (414) 542-9071.
Speakers, observatory open house and talks: June 19, Saturn; July 3, the Moon; July 17, galaxies; July 31, the Milky Way; August 14, meteorites; August 28, stars; $1 donation for parking; tours for groups of ten or more. *Monthly meetings third Friday.*

CANADA

Alberta

Edmonton Centre of the Royal Astronomical Society of Canada. Edmonton Space Sciences Centre, 11211-142 Street, Edmonton, T5M 4A1. (403) 451-7722.
Public lectures, annual public star party, weekly public observing, interests in telescope making, variable stars, comets, astrophotography. *Meeting second Monday of June.*

British Columbia

Okanagan Astronomical Society. 4100 25th Avenue, Vernon, V1T 1P4. Peter Kuzel, (604) 545-1226.
Sponsors annual Mount Kobau Star Party August 20-24.

Royal Astronomical Society of Canada — Vancouver Centre. Gordon Southam Observatory, 1100 Chestnut Street, Vancouver, VJ9 3J9.
Star Parties. *Monthly meetings second Tuesday.*

Royal Astronomical Society of Canada — Victoria Centre. 1230 Verdier Avenue — 102, Brentwood Bay, V0S 1A0. Muriel Enock, (604) 652-9460.
Telescope making, variable-star, comet, and general observing, astrophotography, weekly observing and public lectures with star parties. *Public observing Saturdays July and August.*

Nova Scotia

Royal Astronomical Society of Canada — Halifax Center. N. S. Museum, 1747 Summer Street, Halifax, B3H 3A6. Doug Pitcairn, (902) 463-7196.
Monthly public observing. *Monthly meetings third Friday 8 p.m.*

Ontario

North York Astronomical Association. 145 St. George Street, #701, Toronto, M5R 2M1. Andreas Gada.
Observing, workshops, dark-sky camping weekends, sponsors annual Starfest convention.

Royal Astronomical Society of Canada —Toronto Centre. McLaughlin Planetarium, 100 Queen's Park, Toronto, M5S 2C6.
Two meetings per month, eclipse activity, trips.

Quebec

La Societe d'Astronomie de Montreal. C.P. 206 Station St. Michel. Montreal, H2A 3L9. Mrs. Huberte Palardy, (514) 254-5993.
Lecture, library, workshops, sponsors C.A.F.T.A. Annual Contest for Telescope Makers August 21-23. *Weekly meeting Tuesday 7:30 p.m.*

Photo composite by Johnny Autery

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LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

Spiral Galaxy M-99 (NGC 4254) in Coma Berenices. Spiral structure detail can be seen visually for this 10th magnitude galaxy. 40 minute photo by Dr. Jack Marling using hypered 2415 film, 24" f/6 telescope and LUMICON Giant EASY-GUIDER.

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Also new 12mm & 16mm NAGLERS

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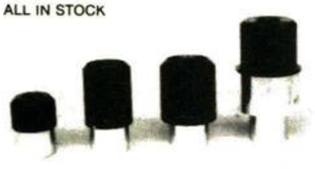

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1.8X or 2.5X Tele Vue Barlow Lens	$89
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$190
15mm Wide-Field, 1¼" eyepiece, 65°	$129
19mm Wide-Field, 1¼" eyepiece, 85°	$139
24mm Wide-Field, "superb," 65°	$159
32mm Wide-Field, 2" eyepiece, 65°	$229
40mm Wide-Field, "awesome," 65°	$289
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$185
9mm Nagler, 82° field, "the best"	$219
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13mm Nagler, 82° field, 1¼" or 2"	$249
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The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
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90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

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UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 85-95%.

"I CAN SEE THE OWL NEBULA!"
Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."* **Tom Kramer, Sayville, NY**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-95%.

	Standard	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		$79.50
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$99.50	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$79.50	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$159.50	$199.50
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		$159.50

LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. .... **1¼" $89.50** **48mm $189.50**

Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines .... **1¼" $99.50, 48mm $199.50**

Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$20.00

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

Upgrade to 48mm filters! All are multicoated

UV, Green, Yellow, Orange, Red	**$18 each**
48mm H-Alpha Pass (640nm cut-off)	$35
48mm Minus Violet (420nm cut-off)	$29
48mm High perform blue, 90% trans	$35
Central Star Filter (blue tri-color) 340-470nm bandpass	$35
UV-370 U-Band, 320-420nm bandpass	$35
48mm Polarizer (2 make variable density)	$18
Set 9 ea. 48mm filters ($259 list)	$195
2"/1¼" adapter threaded for 48mm filters	$20

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	$35.00	$29.00
52, 55, 58, 62mm	$45.00	$35.00
67, 72, 77mm	$52.00	$45.00
82mm	$55.00	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

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DEEP-SKY ASTROPHOTOGRAPHY

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LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

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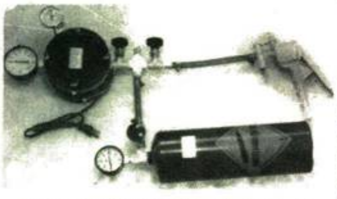
MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

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Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	$169.50
3X Relay Diagonal (see photo)	$79.50
Illuminated reticle eyepiece system	$89.50

Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

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For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)...... **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

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1. Illuminated reticle eyepiece **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
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NEW Deluxe Digital Qtz. Drive Correc. **$298**

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HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	$10.95
SR1600, fastest of all, color neg	24	$12.95
Konica SR200, fine grain color neg	12	$9.95
3M 1000, fastest slide film	20	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
5072, color slides from neg	36	$6.95
D-19 B&W Developer	1 gal.	$6.95

NEW! Meade 2120/GEM and 2080/GEM

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Meade® TELESCOPES AT LUMICON

MEADE 2080/LX3 w/MCSO $1685

#712 Dew shield (8") and accessory tray ($140 list) **add $89**

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2080/LX3
$1685
2080/LX3
W/MCSO

NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

2120/LX3 10'' System w/MCSO $2590

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see Meade ads in this magazine for full list of features.)

4'' MEADE 2045 w/table tripod $598

NEW! Meade 2045/LX3 w/quartz drive **$795**

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Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THE MEADE 2045

- ★ 4" f/10 Schmidt-Cassegrain optics, F=1000mm
- ★ Motor drive for automatic tracking, 110 VAC input
- ★ **LX3:** quartz-controlled elec. drive, 12VDC or 110VAC input
- ★ High transmission coatings on front corrector lens
- ★ Table tripod for easy polar alignment
- ★ 5X24 finderscope & 1¼" right-angle star diagonal
- ★ 1¼" 25mm (40X) and 9mm (111X) eyepieces
- ★ Fork mount with setting circles, manual slow motion

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Model 43 drive corrector uses 12VDC ($130 list) **$99**
See Meade 2080/LX3 options
Wedge & field tripod for Meade 2045 ($380 list) **$298**
Dew shield ($80 list) .. **$55** Solar Filter ($180) **$139**

SUPER

MEADE 2080/GEM $885, w/MCSO $998

SALE

MEADE 2120/GEM $1799, w/MCSO $1949

The Meade 2080/GEM and 2120/GEM telescopes include the same diffraction limited optics as the 2080/2120/LX3. Large, stable German Equatorial Mount (GEM) with setting circles, slow motion controls on both axes, large 8X50mm finderscope, 25mm 1¼" eyepiece, integrated polar alignment scope, and heavy duty adjustable height tripod (hardwood for 2080, metal for 2120). The computer control provides automatic object location from an extensive software library of deep-sky objects.

Meade 2080/GEM, 8" f/10 Schmidt-Cassegrain telescope with equatorial mount ($2100 list) **$885**
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Meade 2120GEM, 10" f/10 Schmidt-Cassegrain telescope with equatorial mount ($4100 list) **$1799**
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Dew shield for 2080/GEM .... **$72** Dew shield & accessory tray for 2120/GEM **$144**
#785 motor and quartz drive corrector system (for photography). **Highly Recommended** ($310 list) **$219**
#3000 computer control system provides automatic celestial object location ($1500 list) .... **add $985**
LUMICON Cassegrain EASY-GUIDER™ with adapter for superb rich-field viewing & photography **$239**
LUMICON DEEP-SKY Filter™ improves **both** viewing and photography, 1¼" premium ..... **$79.50** 48mm **$119.50**

8'' f/6 NEWTONIAN..........$995

$698 (Model 628)

$798 (Model 628C) 6'' f/8 with motor drive

Model 826, 8'' f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)........ **$698**
Model 628C, 628 w/2" focuser, 8x50mm finder ($1500). **$798**
Model 826C, 8" f/6 with motor drive, #680 2" focuser and 8x50mm finderscope ($1640 list)...................... **$995**
—Collects 78% more light than a 6" telescope.

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 2" rack & pinion focuser, 8X50 finderscope (628C & 826C only), 25mm (48X) and 9mm (135X) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alignment.

#43 drive corrector uses 12VDC ($130 list).............. **$99**
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1¼" or 2" EASY-GUIDER (state camera)............. **$169**

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼" **$79**
Prem 1¼", **$99;** Std 48mm, **$159.50;** Prem 48mm, **$199.50**
LUMICON Deep-Sky Filter, 1¼" Premium **$79**
48mm Prem Deep-Sky ...... **$119.50, $99.95** w/Easy-Guider
Adapter for viewing w/1¼" eyepiece **$20**
Dust covers. Keep optics clean. For 6" **$16/pair**
8" .... **$20/pair;** 10" .... **$18;** 16" **$24**
LUMICON Rich-Field Viewer (2080) **$140**
LUMICON Newtonian Easy-Guider, 1¼" or 2" **$169**
#122 2X Barlow ($70 list) **$56**
Dual-axis drive corr. and elec. dec. for 2080/LX3 ... $198
for model 628, 826, DS-10 .... **$340** for DS-16 .... **$440**
Tele Vue 32mm Plossl 1¼" eyepiece .... **add $99**
LUMICON Cassegrain EASY-GUIDER for Meade 2045, 2080/LX3 and 2080/GEM (state camera) **$225**
Illuminated reticle eyepiece & battery pack **$89.00**

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6'' f/5 NEWTONIAN........$695

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STILL AVAILABLE AT 1985 PRICES!

Models 6600 (6" f/5) & **8800** (8" f/4.5) telescopes
Model 6600, 6" f/5 Newtonian telescopes ($1400 list)..**$695**
—Best performance & value; bright, wide views.
Model 8800, 8" f/4.5 Newtonian Telescopes ($1800)...**$895**
—Collects 78% more light than a 6" telescope.

These Meade Professional Series reflecting telescopes yield superb rich-field viewing w/bright images. They include an equatorial mount w/adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces & accessory tray.

#784 motor & quartz drive corrector ($310 list)........ **$219**
Basic camera adapter (for moon & planets)........... **$32**
1¼" LUMICON Easy-Guider (state camera)........... **$169**

16'' f/4.5 NEWTONIAN......$1995

STILL AVAILABLE AT 1985 PRICES!

Meade DS-16A with Accessories

The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($1600 list)......... **$995**
—Gathers 56% more light than an 8" telescope
DS-16A, 16" f/4.5 with motor drive ($3140 list)......... **$1995**
Sealmaster ball bearings, highly recommended... **add $229**
—Gathers 400% more light than an 8" telescope

Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces. The DS-10A is shipped freight collect.

6x30mm finderscope with brackets ($56 list)........... **$42**
8x50mm finderscope with brackets ($130 list)........... **$96**

AstroNews

NGC-262 Found to Be the Largest Isolated Galaxy

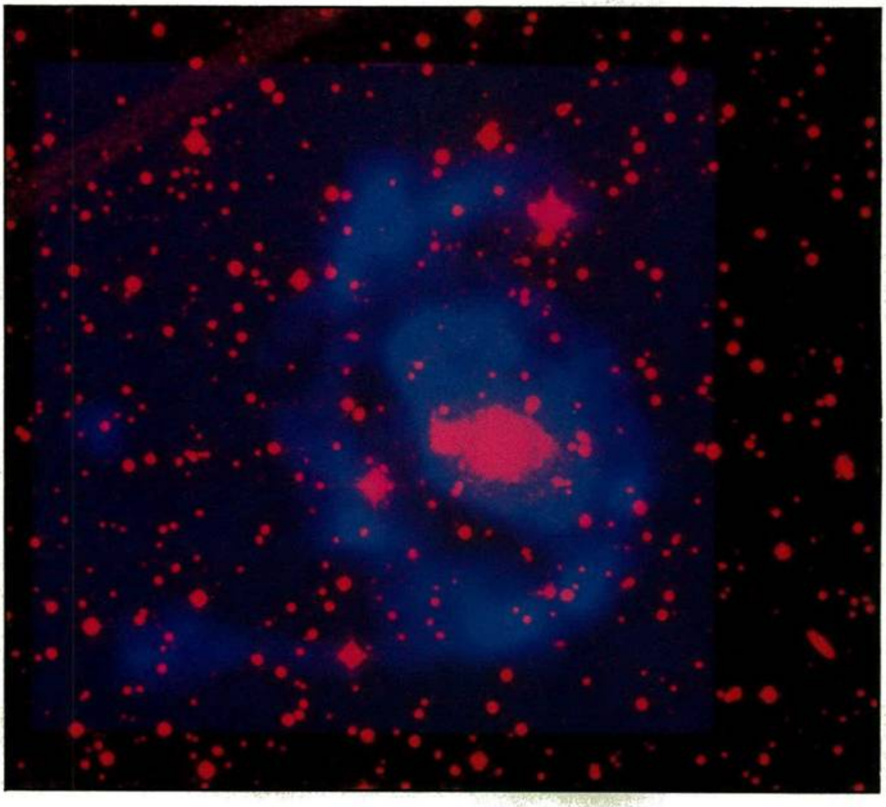
According to a study by astronomers using the Very Large Array (VLA) radio telescope in Socorro, New Mexico, the 15th-magnitude Sa-type galaxy NGC-262 in Andromeda is the largest noncluster galaxy known in the universe. New composite images of this galaxy, also known as Markarian 348, show that its diameter is between 310 and 390 kiloparsecs — about ten to fifteen times larger than the Milky Way.

Susan M. Simkin and Hong-Jun Su of Michigan State University and Jacqueline van Gorkom and John Hibbard of the VLA studied NGC-262 in a recent survey of galaxies. The group is observing unusual galaxies using combined optical and radio images, which can provide a new look at the sizes, masses, and evolutionary histories of these objects.

Viewed with a large telescope, NGC-262 appears rather ordinary: it is a faint, fuzzy disk measuring 1.4′ across with a bright, starlike center. This isn't surprising, because its considerable distance of 60 megaparsecs should prevent seeing much detail in the galaxy. Its bright center, however, is a clue to its nature — NGC-262 is a Seyfert galaxy with a highly energetic nucleus. Until Simkin's study the Seyfert nature of NGC-262 was considered its only abnormal characteristic.

The composite image produced by Simkin's team shows the optical image of NGC-262 in red, superimposed on a bluish radio image. The radio image shows an enormous, spiral-shaped neutral hydrogen cloud surrounding the galaxy, and this cloud increases the galaxy's dimensions to record size for a noncluster galaxy. Moreover, the hydrogen cloud is distorted and is being stripped away by a smaller galaxy nearby called NGC-266.

This tidal interaction between NGC-262 and the diminutive NGC-266 presumably causes the hydrogen cloud's enormous size and warped architecture. The smaller galaxy's passage could also have started the spiraling motion of NGC-262. If this is true, Simkin and her colleagues may be able to show a connection between interacting galaxies and the formation of spiral arms, potentially a highly significant clue to the question: "Why do galaxies have spiral arms?"



This image of NGC-262 shows stars in red and neutral hydrogen in blue. The extensive, distorted hydrogen cloud measures between 310 and 390 kiloparsecs in diameter and makes NGC-262 the largest noncluster galaxy known. Photo by S. M. Simkin, J. H. van Gorkom, J. Hibbard, and H. J. Su, courtesy National Radio Astronomy Observatory/ Associated Universities, Inc.

Recent Martian Volcanism Indicated by New Study

Evidence of recent volcanic activity has been found in a region of Mars where volcanism has never been documented before. High-resolution Viking Orbiter 1 images of the Valles Marineris equatorial rift system, a vast canyon that stretches east to west for more than 4,500 kilometers, revealed dark patches in craters and along fault lines in the troughs of central Valles Marineris, which could be the locations of volcanic vents.

Similarly shaded material is apparent on the Moon and is generally thought to be formed by rock fragmentation resulting from volcanic eruptions. However, because most of the dark patches on Mars are located in craters and thus probably deposited there by wind, the association between these dark areas and local volcanic vents was not considered until now.

According to an article by Baerbel Lucchitta of the U.S. Geological Survey in the January 30, 1987, issue of *Science*, the dark patches in Valles Marineris occur mainly along tectonic structures — faults and scarps built up by the large-scale movements of the planet's crust.

The strongest evidence for volcanism was found in Coprates Chasma in the eastern part of Valles Marineris. Lucchitta reports that the patches occur predominantly along a fault system at the bases of the north wall in Coprates Chasma. The preferential location of these dark patches along fault lines, Lucchitta says, rules out wind accumulation as a cause. Moreover, the dark material can be found on top of landslide deposits, which suggests the material was laid down fairly recently, perhaps only a few million years ago.

The floor of Coprates Chasma is crossed by a fault along which the dark patches extend intermittently for two hundred kilometers. In places the dark areas exhibit streaks, which may be the results of blasts from volcanic vents. That the wind has not yet eroded these streaks implies the streaks are young. The low reflectivity of these features also indicates a young age because the planet's frequent dust storms have yet to bury the patches with fine, light-colored dust.

If volcanism is the explanation for the dark material in Valles Marineris and if the volcanic activity is as recent as these observations suggest, then possibly Mars has been more geologically active throughout its history than previously suspected.

Listening to the Universe on More Channels

NASA's Search for Extraterrestrial Intelligence (SETI) program is now better equipped to detect signals transmitted by extraterrestrial intelligence thanks to a new computer chip developed by graduate students at Stanford University.

The new computer chip has two advantages over the circuits the NASA SETI program currently uses: it will increase to 10 million the number of channels researchers listen to and reduce the cost of the spectrum analyzer, which scans received radio signals looking for unusual noises. The chip is forty times more powerful than the circuits now used.

Radio signals are collected by NASA's 85-foot-diameter Deep Space Network radio telescope in the Mojave Desert. Engineers at Stanford are currently focusing on about one thousand stars and listening to them in the microwave portion of the radio spectrum, the area of the spectrum with the least interference. "Unusual" signals detected by the spectrum analyzer become candidates for further analysis and observation.

According to Ivan Lincott, the Stanford team leader, unusual (not repeated) signals have been detected but not confirmed as signals from extraterrestrial life.

Stanford University receives about $500,000 a year from NASA for the extraterrestrial search, according to Allen Peterson, faculty advisor for the team.

Voyagers 1 and 2 Sampling Cosmic Rays

Scientists hope to gain a better understanding of cosmic rays and energy sources in our Galaxy by studying data collected by instrument packages on board Voyagers 1 and 2.

Cosmic rays are highly energetic particles that move through space at nearly the speed of light, continuously showering the Earth from all directions. The nature of cosmic ray sources and the motions of cosmic rays through the Galaxy and the solar system have been a mystery since the sources were discovered by V. F. Hess during a balloon flight in 1912.

Robert Decker and S. M. Krimigis from the Johns Hopkins University Applied Physics Laboratory and D. Venkatesan of the University of Calgary are collecting data on these ubiquitous particles using the Low Energy Charged Particle Experiments on Voyagers 1 and 2. So far their data confirms the theory that the concentration of cosmic rays increases closer to edge of the heliosphere, the region of the expanding solar winds that surrounds the Sun and solar system.

Scientists are expecting to find cosmic rays undisturbed by the solar wind when the spacecraft leave the heliosphere. Voyager 1 is already 29 astronomical units from the Sun and could pass beyond the heliosphere in about twenty years. Voyager 2, which is providing comparative cosmic ray data, is 22 astronomical units from the Sun and on a different trajectory. That spacecraft is currently en route to an encounter with Neptune on August 25, 1989.

Both Voyager spacecraft have at least a twenty-year supply of attitude-control fuel, which is used periodically to turn the spacecraft so data can be received on Earth. Voyager scientists hope this fuel can be conserved so the spacecraft can transmit data once they pass beyond the heliosphere.

Pre-Solar System Diamonds Found in Meteorites

What may be the oldest particles ever examined in the laboratory — microscopic diamonds that predate the formation of the solar system — have been discovered in meteorites by scientists at the University of Chicago.

The diamonds are believed to have formed in the atmosphere of a distant star

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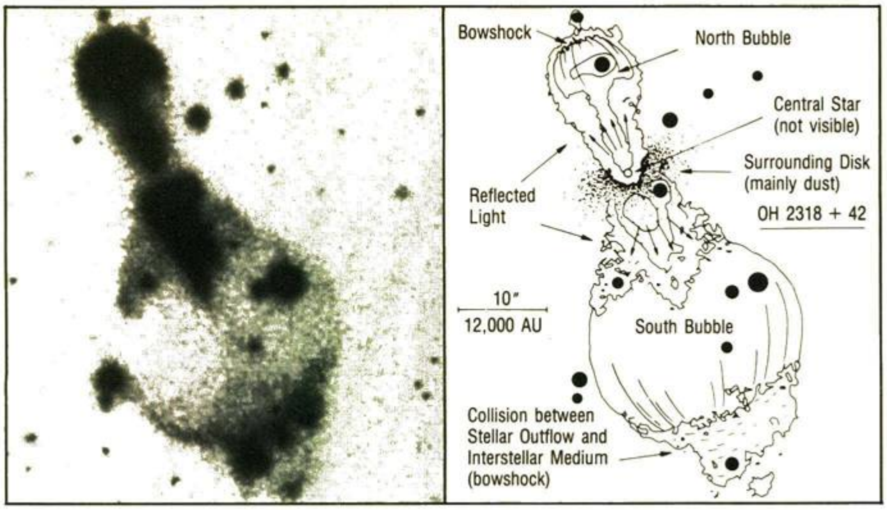

This red CCD image of the peculiar object OH 231.8+4.2 (left) shows for the first time a star during its rapid transition from a red giant to a white dwarf. The star is embedded in a dense dust disk and material is ejected into two "bubbles." Shocked regions occur where high-speed stellar material collides with interstellar gas and dust. In this photo north is up and east to the left. Courtesy European Southern Observatory.

and then spread throughout space when the star exploded as a supernova, according to the researchers' report in the March 12, 1987, issue of *Nature*. The diamond particles were incorporated into the cloud of interstellar gas and dust from which our solar system evolved, but, unlike the other particles in that primal cloud, the diamonds managed to survive — unchanged — the intense heat of formation.

The discovery implies that diamonds are relatively common in interstellar space. Chicago physicist Roy Lewis, one of the researchers, says "carbon is very common in interstellar clouds. Most of it is in the form of graphite or amorphous carbon and carbon compounds but some of the interstellar carbon must be diamond."

"This work suggests that the formation of diamond occurs on an enormous scale in the universe," according to co-author Edward Anders. The diamond grains would have formed in the low-pressure environment of a red giant star and collected in the dense dust shell surrounding the star. Although diamonds are normally created only under extreme pressures, recent laboratory studies have shown diamonds can form at low pressures from hot gases containing carbon.

The diamonds, which are essentially remnants from a supernova, may help solve questions about stellar evolution and the formation of the solar system.

Bubbles from a Dying Star

All stars are born the same way, from matter condensing in large interstellar clouds of gas and dust, but all stars do not die the same way. Massive stars may end their lives in spectacular supernovae explosions, while less massive stars like the Sun end their existence in less dramatic fashion. For example, once the Sun has exhausted its nuclear fuel, it will grow more than a hundredfold in size and become a red giant. After that stage it will rapidly shed its outer layers, leaving only a white dwarf star behind.

Until recently no one had ever witnessed a solarlike star undergoing the transformation from red giant to white dwarf. In February, however, astronomer Bo Reipurth concluded a study of the peculiar star OH 231.8+4.2, a faint star about 1.2 kiloparsecs away in the constellation Puppis. Using the Danish 1.5-meter telescope at the European Southern Observatory in La Silla, Chile, Reipurth obtained CCD photographs of OH 231.8+4.2 in the red light of hydrogen, nitrogen, and sulphur and discovered a bizarre series of shells and bubbles involved with the star.

OH 231.8+4.2 itself is not visible in the photographs but is embedded within obscuring dust. The "bubble" nebula surrounding the star is shaped like a figure eight and consists of matter ejected from the star. The dark band around the "waist" of the nebula is a dense disk of dust particles that blocks light from behind it. Light from the innermost part of the nebula is reflected light from the star, but the light from the bubbles is emitted from regions where the rapidly moving nebulosity collides with surrounding interstellar gas.

The star is losing mass rapidly. Since the diameter of the southern part of the nebula is about 50,000 astronomical units, astronomers can calculate that the nebula is only some 1,400 years old — an infant on the cosmic timescale.

As OH 231.8+4.2 sheds a larger portion of its mass, the surrounding nebula will become increasingly rarefied. The entire object will then be a planetary nebula, consisting of a diffuse mass of gas glowing by ionization from the hot white dwarf star in its center. Then, when the surrounding gas has dispersed into space, only the white dwarf will be left as a ghostly memorial to the once brilliant star.

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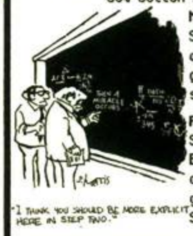

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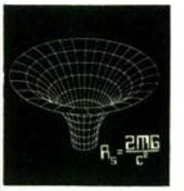

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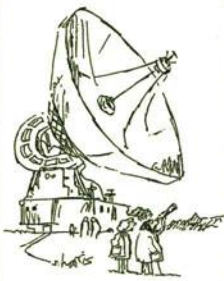

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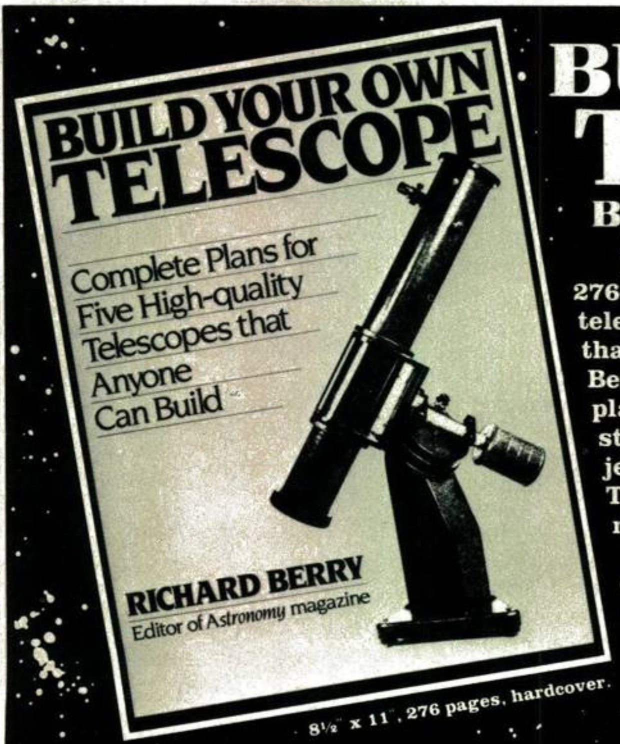
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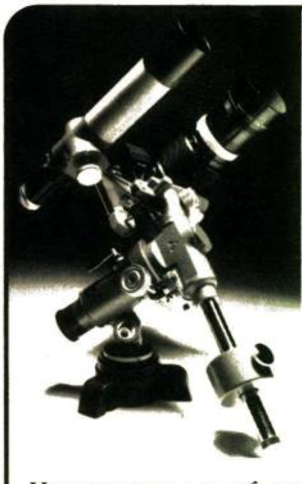

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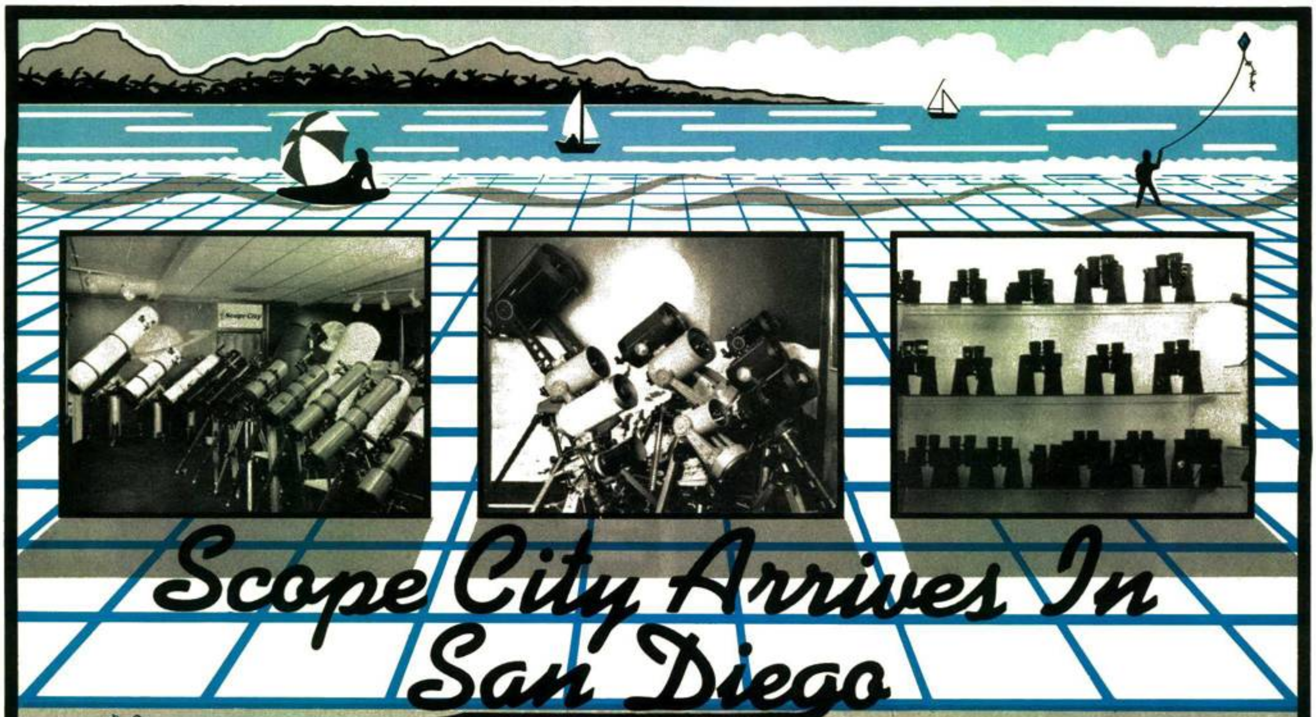
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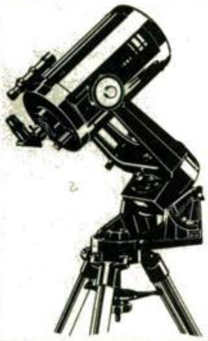

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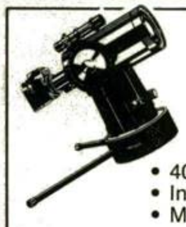

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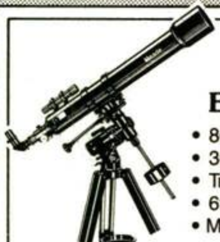

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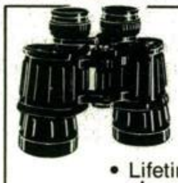

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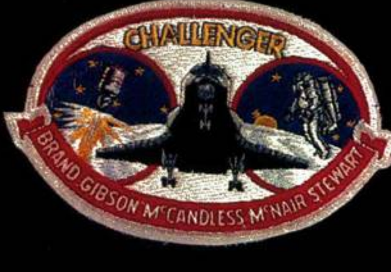
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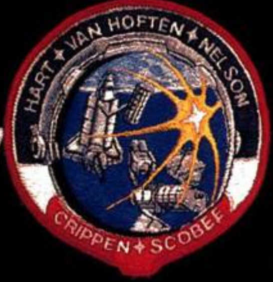
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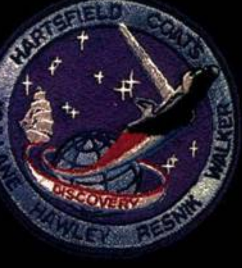
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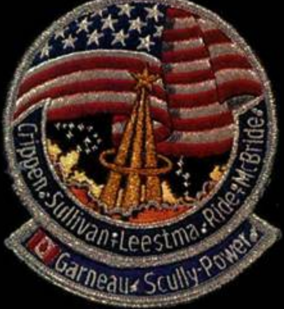
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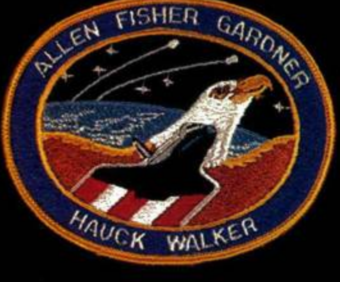
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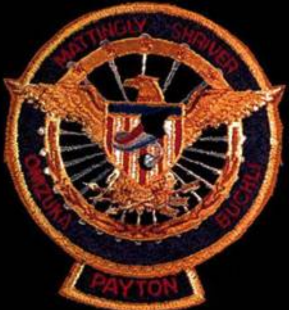
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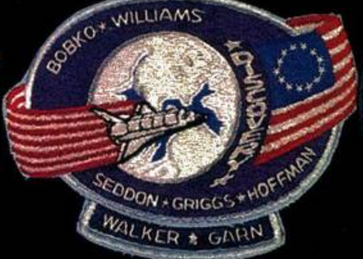
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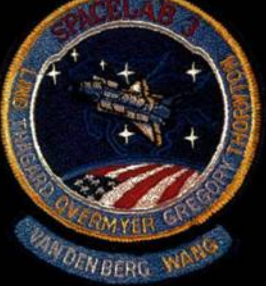
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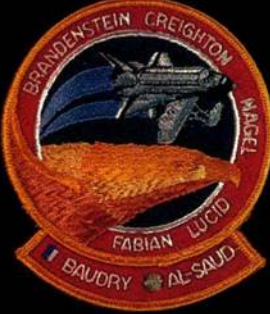
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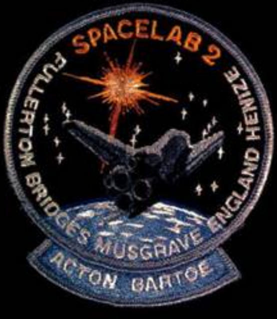
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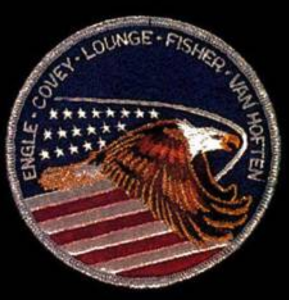
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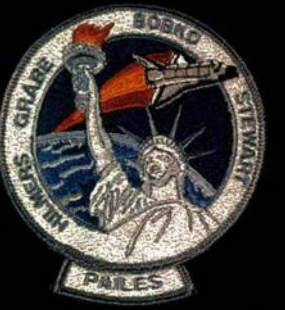
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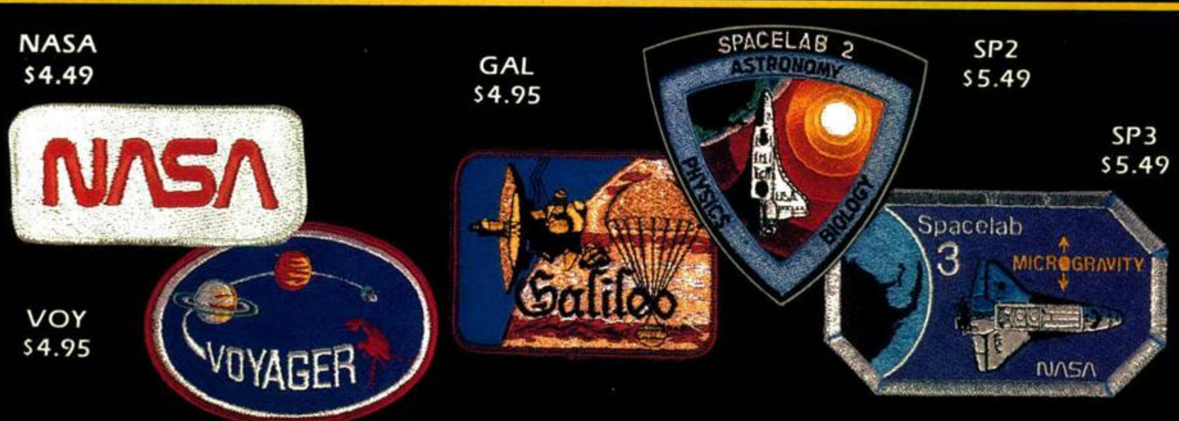
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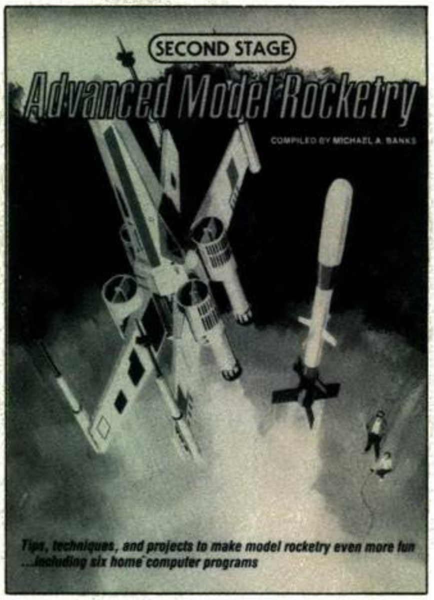
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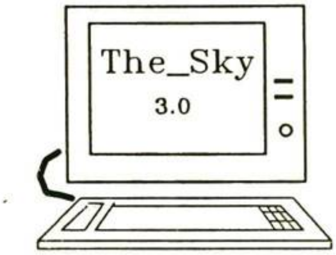

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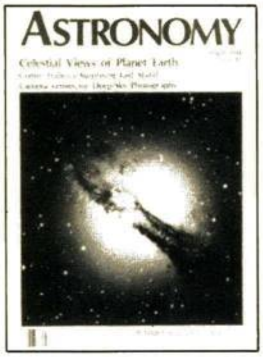

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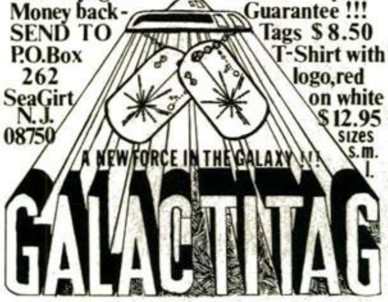
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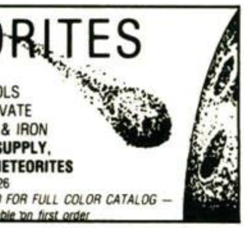

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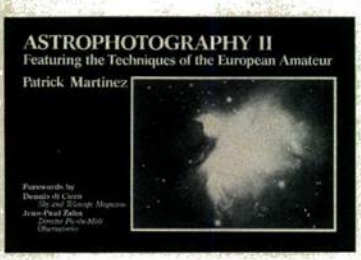

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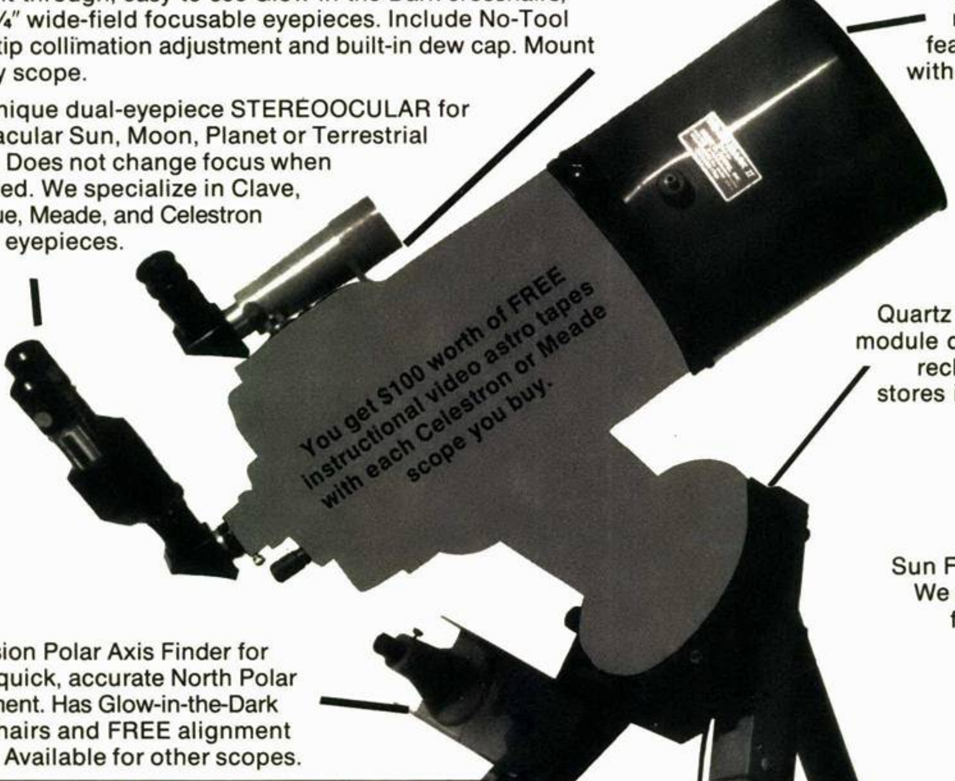

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A Burst of Discovery

The First Days of Supernova 1987A

by Richard Talcott

European Southern Observatory

The brightest supernova since the invention of the telescope has sent astronomers into a flurry of activity.

The night of February 23 began like countless other nights. High in the Andes Mountains of northern Chile astronomers prepared for another night of research, carrying out observing programs planned and approved months before. Little did they realize there would not be another "normal" night for a long time.

Ian Shelton, a University of Toronto research assistant working at the university's Las Campanas station, began making a three-hour exposure of the Large Magellanic Cloud just after 9 p.m. with the observatory's 25-cm (10-inch) astrograph telescope. (The Large Magellanic Cloud, or LMC, and its companion the Small Magellanic Cloud are satellite galaxies to the Milky Way and our closest galactic neighbors.) When he developed the plate something remarkable and totally unexpected was on it: a 5th-magnitude star lying within the Cloud where previously there hadn't been one. For an object to appear so bright at such a great distance (the LMC is about 53,000 parsecs, or 170,000 light-years, away), it must be extremely luminous. After considering all other possible explanations, Shelton realized this object was a supernova.

A supernova marks the final, cataclysmic stage in the lives of some stars. When the star's core can no longer support the weight of overlying material, the core collapses, causing the star to explode. The energy released by the explosion is so great that for a period of a few weeks the supernova may outshine its entire host galaxy.

Astronomers spot about twenty to twenty-five supernovae each year; a total of more than six hundred have been observed. Most occur in galaxies far beyond our own. The last observed supernova in the Milky Way was Kepler's supernova in 1604, five years before Galileo first turned his primitive telescope toward the sky. The only supernova since then to achieve naked-eye visibility occurred in 1885 in the Andromeda Nebula. At the time no one knew this nebula was a galaxy and therefore at a great distance, so the 6th-magnitude object was not recognized as a supernova.

The current supernova provides astronomers with tremendous opportunities. Stan Woosley, an astronomer at Lick Observatory, says: "The reason this supernova is so special is not because it's the closest, but because this is the first one we've seen in the Large Magellanic Cloud." He goes on to explain that there are many supernovae in our Galaxy we can't see because they are obscured by interstellar dust. And even if we could see one, determining its distance accurately would be difficult. The LMC supernova is close enough for us to observe it in detail, it is not blocked from view by intervening dust, and the distance to the galaxy it belongs to is well-known.

Shelton discovered the LMC supernova when he examined his photographic plate at approximately 5:30 Universal Time (UT), or 12:30 a.m. EST, on the 24th. At about the same time Oscar Duhalde, a telescope operator at Las Campanas Observatory, spotted the supernova visually. A third independent sighting came from amateur Albert Jones in Nelson, New Zealand, at 9:00 UT on February 24. As the first supernova spotted in 1987, this one was officially designated 1987A.

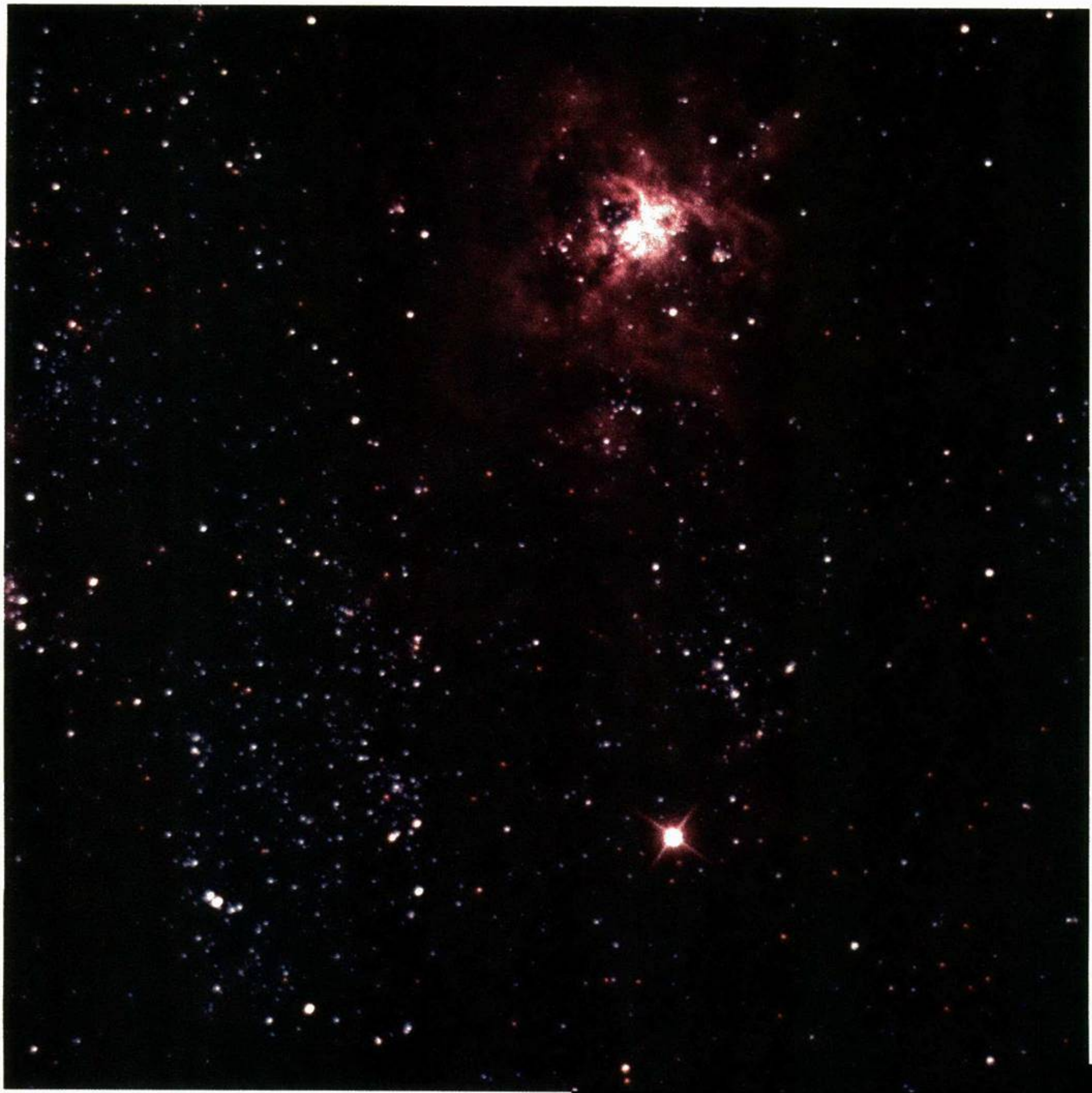
That morning the astronomers in Chile sent a telegram announcing the discovery to Brian Marsden at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. Marsden is in charge of the International Astronomical Union's Central Bureau for Astronomical Telegrams, a service that keeps astronomers abreast of the latest astronomical discoveries and developments. News of the supernova spread rapidly through the astronomical community by word of mouth and through telegrams published by the Central Bureau.

Observations from the first brief night were tantalizing, but there was not much solid information. Robert McNaught of Siding Spring Observatory in Australia determined a reasonably accurate position for the supernova. It was located some 20 arcminutes southwest of 30 Doradus — also known as the Tarantula Nebula — a region that has been studied extensively over the years because of its multitude of hot, young stars. Several observers estimated the supernova's apparent visual magnitude: all the measurements were within a few tenths of magnitude 4.5.

Many astronomers tried to guess how bright the supernova would become. Such a calculation depends on many assumptions, but the general consensus — based on the distance to the LMC and observations of past supernovae — was that 1987A would brighten to at least 1st magnitude and possibly become as bright as Jupiter. It would make little difference to Northern Hemisphere observers, however, because the supernova was not visible north of 20° north latitude.

What Type of Beast Is 1987A?

On the next night all the major Southern Hemisphere observatories were prepared for 1987A. Astronomers in Chile, South



Supernova 1987A in the Large Magellanic Cloud was shining at magnitude 4.5 on March 1, when Jim Barclay photographed it with a 12.5-inch Newtonian from Queensland, Australia. The supernova is the brightest object in the lower half of the photo; the Tarantula Nebula dominates the upper half.

Africa, Australia, and New Zealand eagerly pointed their telescopes toward the supernova. The nearness of the explosion offered a unique opportunity to study the aftermath.

Night settled first across South Africa. Spectroscopic observations of the supernova, taken with the 1.9-meter telescope of the South African Astronomical Observatory by J. Menzies around 21:30 UT on February 24, showed a prominent absorption line near 6150 angstroms. Identifying a supernova spectrum is an extremely difficult task, particularly for researchers unaccustomed to dealing with the spectra. Since many of the observers in the Southern Hemisphere went there to work on other projects, problems inevitably arose. After a lengthy phone conversation with University of Texas astronomers, they preliminarily concluded that the absorption line came from ionized silicon, and therefore that 1987A might be a Type I supernova.

Astronomers believe most Type I supernovae arise in binary star systems containing a white dwarf. (A white dwarf is a star that has exhausted its supply of nuclear fuel and has been compressed by gravity to a sphere about the size of Earth.) The white dwarf has a core made of carbon and oxygen surrounded by a layer of helium — the hydrogen present early in its life has either been converted into helium or ejected into space earlier in the star's evolution.

If the white dwarf accretes matter from its companion star and if the internal pressure of the white dwarf is not great enough to support this extra material, the temperature in the core rises to the point where carbon burning ignites. Nuclear fusion reactions then rapidly propagate outward and destroy the star.

The resulting supernova quickly brightens and then slowly fades. (A chart of the supernova's brightness with respect to time is called a light curve.) The spectrum of a Type I supernova is devoid of hydrogen because the white dwarf doesn't contain any hydrogen at the time of the explosion. Theoretical models predict that the nuclear reactions causing the supernova create about one solar mass of Ni^{56} (nickel with an atomic weight of 56), which decays first to cobalt (Co^{56}) and then to iron (Fe^{56}). The radioactive decay of Ni^{56} and Co^{56} completely explains the postmaximum light curves of Type I supernovae.

Back at Las Campanas Observatory later that same night Arthur Davidsen, Randy Kimble, and Michael Gregg took spectra of the supernova with the observatory's 2.5-meter telescope and tentatively identified several hydrogen absorption lines. Because the presence of hydrogen in a supernova spectrum classifies it as a Type II object, opinion began to swing the other way within hours. Over the next several days more and more astronomers reported the detection of hydrogen in the supernova's spectrum, and a consensus that 1987A was a Type II supernova developed. The ambiguous absorption line in the early spectrum was not due to silicon but to the shifting of the H-alpha line of hydrogen from its normal position because of the supernova's rapid expansion.

A Type II supernova occurs when a red supergiant star larger than about eight times the mass of the Sun runs out of nuclear fuel. Such a massive star begins life as other stars do — converting hydrogen into helium in its core. This conversion occurs at a prodigious rate, however, and within a few million years — compared to some 10 billion years for the Sun — the hydrogen in the core is used up. The weight of the overlying gas then raises the central pressure and temperature high enough to start the helium burning process. The process of creating heavier elements and then utilizing them in nuclear reactions continues as first carbon, then neon, oxygen, and silicon form.

These reactions occur at ever increasing rates as the temperature in the core continues to rise. Helium burning may take half a million years, but silicon is converted into iron in only one day. This is where the process stops. Because iron is the most stable element, no energy can be generated by nuclear reactions in the iron core. Without energy there is no internal source of pressure to support the overlying layers, and the core collapses catastrophically (in less than a second). This implosion stops abruptly when the core is compressed to the density of an atomic nucleus, and a shock wave is created that propagates outward. This shock wave literally blows the rest of the star into space, creating the supernova.

At maximum light a Type II supernova is usually about two magnitudes fainter than a Type I, although there is much more variation in the Type II class. Its spectrum is dominated by the hydrogen present in the outermost layers of the presupernova star. All that remains of the original star is the compact iron core with a density of an atomic nucleus — a neutron star. In fact, astronomers consider Type II supernovae the sole source of neutron stars. These stellar explosions are also important because they release large quantities of heavy elements into space. Most of the elements between helium and iron are formed in massive stars and ejected during supernovae explosions, while all the elements heavier than iron are formed in the final seconds of stellar collapse.

What Came Before?

One of the more exciting features of the LMC supernova was the possibility of locating the star that exploded. Astronomers would love to study a star destined to be a supernova before the outburst occurs, but they have never had the opportunity because such a star is dim before the explosion, and there are innumerable candidates to choose from. But observations of a presupernova star, or progenitor, would be extremely valuable and could have a profound impact on our understanding of supernovae and stellar evolution in general. Since the region surrounding 30 Doradus had been photographed and mapped extensively, the astronomical community felt that a progenitor might be found at last.

The major problem facing astronomers trying to identify the progenitor was the brightness of 1987A itself. Since most of the stars in the supernova's immediate vicinity were lost in the glare of the supernova, astronomers could not tell which stars were still shining and which one was not. With such a high scientific reward, however, astronomers sought an alternate method.

McNaught identified a potential progenitor on older photographic plates based on his preliminary positional measurements. The star was cataloged in 1968 by Nicholas Sanduleak of Case Western Reserve University and is known as Sanduleak −69°202. It is a hot supergiant star of spectral class B3 and magnitude 12. Other astronomers also noted the coincidence between the position of the supernova and that of Sanduleak −69°202. A close examination of earlier photographs revealed that the star has two close companions, one about 2.5 arcseconds away and the other less than one arcsecond distant.

Within two days of the supernova's discovery, European Southern Observatory astronomers in La Silla, Chile, reduced the positional errors to less than one-quarter of an arcsecond, which allowed them to rule out the more distant companion as the progenitor. They could not be certain which of the other two had exploded, but they were confident one of them had.

Remaining at Constant Light

The most surprising aspect of 1987A's behavior during the first week was its nearly constant light output. On the night of discovery the supernova shone at about magnitude 4.5, at least eight magnitudes brighter than on the previous night. Preliminary observations on February 24 indicated the supernova was

The region surrounding the Tarantula Nebula looked the same as it had for thousands of years on November 22, 1986 (left). By March 2, 1987 (right), a week after the LMC supernova blazed into view, 1987A rivaled the Tarantula Nebula in brightness. The supernova is the bright star at the middle of the right edge of the frame. Both photos were taken by Chris Floyd with a 10-inch Newtonian reflector from Sandy Creek, South Australia.

continuing to brighten but at a dramatically slower pace. However, two days later the visual magnitude had only reached 4.3, and it did not change appreciably in the four weeks after that.

It appears then that 1987A does not fit the classical model for Type II supernovae. A typical Type II brightens rapidly, reaches a maximum within a couple of days, and then fades slowly. In about one-quarter of the observed cases the dimming occurs at a nearly constant rate for the first one hundred days and then slows down. In two-thirds of the cases the dimming stops after a week to ten days. The supernova's luminosity then remains nearly constant for approximately one hundred days before falling off again. The remainder of Type II supernovae do not behave in any consistent way.

University of Texas astronomer Gerard de Vaucouleurs and Paul Murdin of the Royal Greenwich Observatory suggested at the end of the first week that the relatively constant brightness of the LMC supernova could be explained in one of two ways: either as the maximum level in a typical Type II outburst or as a "premaximum halt" that would soon be surpassed. They cited two previous supernovae, 1940B and 1941A, as precedents for the latter view. Both of these supernovae rose to an uncharacteristically low luminosity and remained at that plateau for approximately twenty days, after which they brightened to a typical Type II level. If 1987A followed this scenario, observers would have seen 1987A brighten to 2nd magnitude sometime around March 20 to 25.

Clues in the Spectrum

Astronomers are just as eager to learn about the spectrum of the supernova as they are about its brightness fluctuations. Locked within the spectrum are clues to the dynamics of the explosion itself as well as the composition of the material ejected.

To determine how fast the shell of ejected material is expanding, for instance, astronomers measure the Doppler shift of its spectral lines. When a source of radiation moves toward or away from the Earth, its spectral lines are shifted to shorter or longer wavelengths, respectively, than they would normally be. This shift is called a Doppler shift and is greater the larger the source's velocity. J. Menzies measured the wavelength of the strongest hydrogen absorption line in the visible spectrum, known as H-alpha, every night from February 24 to March 3. At about 21:30 UT on February 24, he found the line shifted by an amount that corresponds to a velocity of approach of about 18,300 kilometers per second. That velocity decreased each day at a steady rate of 780 kilometers per second. This and other similar spectroscopic data gave scientists their first detailed look at how a supernova explosion evolves.

The light from the supernova also provides, surprisingly enough, a delicate probe of the material between ourselves and the LMC. Steve Shore of the New Mexico Institute of Mining and Technology explains that "the supernova lit up the interstellar medium like a flashbulb." As the light from 1987A passes through intervening clouds of gas, the gas absorbs specific wavelengths of light that depend on its composition. Each cloud leaves an individual signature in the spectrum of the supernova. Astronomers at the European Southern Observatory detected more than twenty absorption lines caused by ionized calcium, as well as thirteen caused by neutral sodium and two from neutral potassium, in very high dispersion spectra of the supernova taken during the first week of the outburst.

These absorption lines offer a direct way of measuring the composition of interstellar clouds in the Milky Way and the LMC and in the clouds of the halo surrounding our Galaxy. Shore calls the supernova "the best probe we've ever had of the interstellar medium and galactic halo."

The first observations of these interstellar absorption lines were not made from the ground, however. The International Ultraviolet Explorer (IUE) satellite began a series of observations of the supernova within hours of the supernova's discovery. Intended for instances just like this, the satellite's "target-of-opportunity" observing program allows observations of unexpected and important events in the ultraviolet part of the spectrum. The initial observations revealed a large number of interstellar absorption lines in the ultraviolet, including six caused by neutral magnesium.

The Color Reddens

As supernovae age, they emit a greater percentage of their radiation at longer wavelengths. There are two reasons for this reddening effect. First, the extremely high temperature that characterizes the initial outburst gradually cools, and cooler objects give off a higher percentage of their light at longer wavelengths. Second, the velocity of the expanding shell slows down as it encounters material in the surrounding area. This slowdown reduces the Doppler blueshift of the emitted spectrum, effectively making the overall color more red.

Studying this color evolution is another area where ground- and space-based observations have been complementary. Only a week after the outburst Shelton and Barry Madore reported that the color of 1987A was reddening about five times faster than is typical for Type II supernovae. Further observations showed that this pattern continued for two weeks after the explosion, when the color of 1987A stabilized. This "plateau phase" is normal for a Type II supernova after it passes peak brightness.

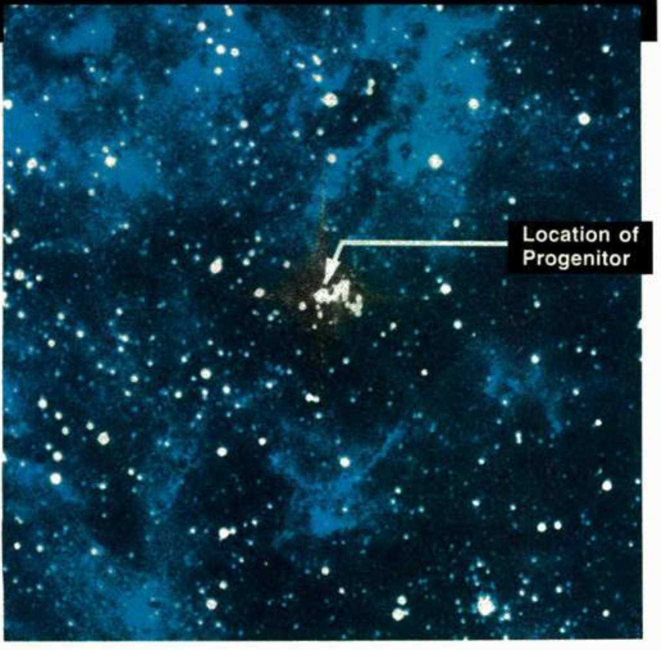
Because ultraviolet radiation has a shorter wavelength than visible light, the reddening is much more pronounced. And observations of this effect by the IUE observatory provided one of the bigger surprises of the first month. The amount of ultraviolet radiation between about 1200 and 1600 angstroms was dropping dramatically within two days of the outburst. Less than a week into the observations the short-wavelength ultraviolet flux from the supernova faded away. What was left was very nearly the spectrum of a B3 supergiant star, the star presumably destroyed by the supernova explosion. Further observations confirmed that Sanduleak −69°202 and at least one of its companions were still shining normally. The suspected "progenitor" was apparently not it, and the search for the real progenitor had to start anew.

If not Sanduleak −69°202, then what? Researchers aren't sure. Shore points out that the progenitor was probably underluminous, adding that "there are many ways to hide a star." He feels it may have been immersed in a dense dust shell — something not unexpected for a massive star near the end of its life — that blocked it from our view. Craig Wheeler from the University of Texas feels the progenitor may yet turn out to be the unresolved second companion of Sanduleak −69°202. The issue won't be settled until 1987A fades enough to allow detailed observations of the area.

Capturing the Elusive Neutrinos

The most important revelation to come from the first few weeks of the outburst was the detection of neutrinos. Neutrinos are extremely elusive particles that interact only very rarely with other matter. Yet they are of vital importance in many areas of physics and astrophysics and in the physics of supernovae.

Identifying the progenitor of 1987A — the star that subsequently exploded — was a major goal during the first weeks of the outburst. It was not an easy task, however, because the bright supernova overwhelmed the light from nearby stars. This image shows the field of the progenitor in 1977 with an outline of the supernova to the same scale. The arrow indicates the position of the star astronomers initially thought was the progenitor. Later observations ruled this star out, although the progenitor may yet prove to be an unresolved companion to the indicated star. European Southern Observatory photo.



Neutrinos have very little or no mass and travel at the speed of light, if they are massless, or close to the speed of light. They are produced in huge numbers inside the collapsing core of a soon-to-be supernova as electrons and protons are squeezed together. The neutrinos formed in this process, in fact, carry off most of the energy in the explosion: roughly one hundred times the energy released as electromagnetic radiation and ten times that of the kinetic energy of the exploding material. A supernova may shine as brightly as an entire galaxy, but Carl Pennypacker, a physicist at the Space Sciences Lab of the University of California at Berkeley, points out that, during the one second that neutrinos are emitted, "in rough numbers the supernova is as bright as the rest of the universe combined in terms of its power output."

Despite this incredible energy neutrinos are very difficult to detect. However, physicists have built a few detectors that can do the job, even though they were designed for a different purpose. The Grand Unified Theories of physics attempt to combine the electromagnetic, strong nuclear, and weak nuclear forces into an all-encompassing framework. The most popular of these theories predicts that the proton is an unstable particle that must eventually decay. To test this hypothesis, several groups built detectors consisting of many tons of water. If any of the protons in the water molecules decayed, the by-products of the event would be recorded. Although no proton decay has yet been found, the huge detectors do stop an occasional neutrino (out of literally trillions that pass through them every second).

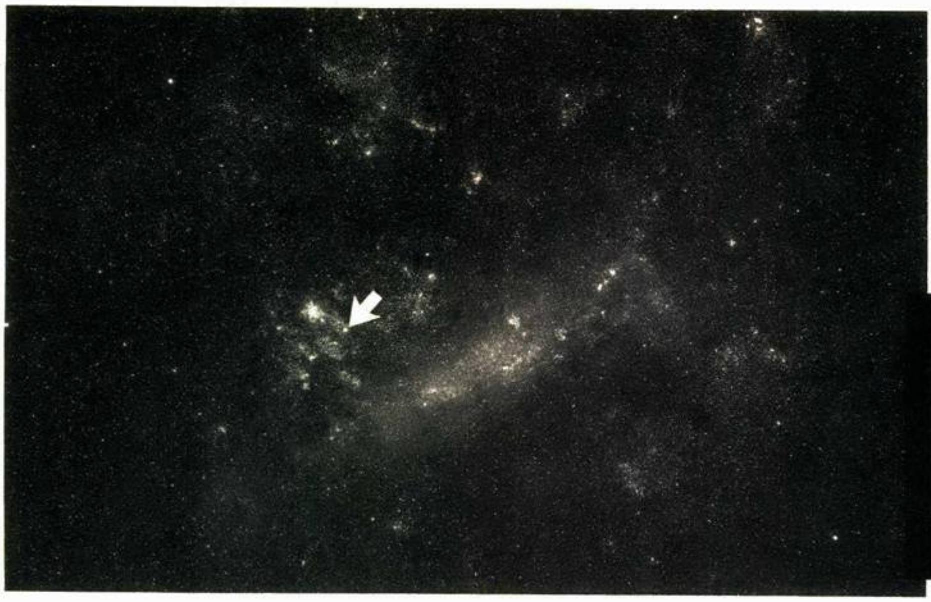
On February 28, G. Castagnoli telexed Brian Marsden stating: "A signal was detected [at about 2:52 UT on February 23] at the Mont Blanc Neutrino Observatory." The observatory, operated by the Instituto di Cosmogeofisica in Turin, Italy, and the Institute of Nuclear Studies in Moscow, recorded five neutrinos in a seven-second interval, figures in reasonable agreement with predictions for a Type II supernova. Castagnoli went on to say that a random observation of this type occurring at the same time as 1987A should happen only once in every 10,000 years. However, rare events do happen.

Ten days later the University of Tokyo, Niigati University, and the University of Pennsylvania announced the results of their collaborative experiment. The Kamiokande-II neutrino experiment recorded eleven neutrino events over a thirteen-second interval. The only problem was the time: this burst arrived at approximately 7:35 UT on February 23, more than 4.5 hours after the Mont Blanc detection. No events were recorded at Kamiokande-II near the time of the Mont Blanc detection.

The resolution of the dilemma came the following day. A University of California at Irvine, University of Michigan, and Brookhaven National Laboratory experiment located in a Morton Thiokol salt mine near Cleveland, Ohio, had also detected neutrinos. According to team member Henry Sobel of the University of California at Irvine: "When we heard about the supernova, we began a sequential search through our records for neutrino observations. We had not found any by the time the Mont Blanc detection was announced, so we concentrated our search around the time of its observation and still found nothing. We had gone back to our sequential search when the Kamiokande-II announcement came out; when we switched to that time we quickly found what we were looking for."

Eight events were recorded in a six-second interval beginning February 23 at 07:35:41.45 UT. The near-perfect coincidence with the Kamiokande-II experiment convinced astronomers that the neutrinos emanating from the collapsing core had been detected. No one was quite sure what to make of the Mont Blanc observation, but most astronomers were quite sure it was unrelated to the supernova.

The observations were "nothing short of spectacular," according to Shore. Woosley says the neutrino observations "tell us something definite — that the iron core collapsed," and Pen-



Ian Shelton of the University of Toronto began this three-hour exposure of the Large Magellanic Cloud, unaware of the sensation it would cause. This reproduction from the discovery plate shows the 5th-magnitude star (indicated by the arrow) that turned out to be the brightest supernova in 383 years. Photo courtesy Robert Garrison, University of Toronto.

nypacker added that "witnessing the gravitational collapse is not only the best astronomy but probably the best physics of the year."

The neutrino observations also constrained models of the progenitor. The neutrinos escaped the collapsing core at the same time the shock wave started propagating outward. By measuring the time it took the shock wave to reach the surface, astronomers could use the known speed of the shock wave to calculate the radius of the progenitor. And the shock wave hit the surface at the same time the supernova began to brighten.

One of the first things astronomers did when they heard about the supernova was look for prediscovery observations. The earliest recorded observation turned out to be a photograph taken at Siding Spring Observatory at 10:38 UT on February 23, which showed the supernova at magnitude 6.0. The supernova was not seen at 9:20 UT that day by Albert Jones in his 30x78 finder scope, the same instrument he used to independently sight 1987A the next day, which implies the supernova was much fainter.

The neutrinos were captured some three hours before the first visual observation, so the shock wave took about three hours to pass through the star. Traveling at a speed of approximately 10,000 kilometers per second for those three hours, the shock wave covered about 100 million kilometers. A radius of this size is more like that of a blue giant than a red supergiant, the stars considered to be likely progenitors of Type II supernovae.

Physicists may also determine the mass of the neutrino, or at least an upper limit to it, from the neutrino data. In addition to the many ramifications this will have in physics, neutrinos with mass could decide the fate of the universe. If there is enough matter in the universe, its present expansion will one day stop and reverse, making ours a "closed" universe. If not, the universe will be "open" and expand forever. There are so many neutrinos that even if each turns out to have only a tiny mass, the total might be enough to close the universe.

What Happens Next?

The first few weeks following the explosion of 1987A were filled with excitement and discovery. Fueled by a rush of adrenaline, astronomers studied the object in every way they possibly could. As the weeks turn into months and the months into years, will the discoveries continue? Will astronomers really get a better picture of the universe from this single event? Most astronomers are answering these questions with a resounding "yes."

The most immediate answers will probably concern the behavior of the supernova's light curve. Whether 1987A fades directly from the plateau phase or follows the scenario suggested by de Vaucouleurs and Murdin will give astronomers better insight into the mechanics of Type II supernovae. The light curve will also help astronomers determine just how peculiar 1987A is and where it fits among other Type II objects.

Perhaps the most fundamental observations will come from studying the composition of the supernova remnant. As the gases expand they become less opaque and reveal details in a way Pennypacker likens to "peeling an onion layer by layer." As succeeding layers are revealed, astronomers will see different elements — the elements created by the star during its life and by the supernova during its death. The helium layer began poking through during the third week after the explosion, and other elements are expected to follow.

Astronomers hope to eventually find Ni^{56} — a radioactive element believed to be created in large quantities in Type II supernovae. Woosley cautions that the detection of Ni^{56} probably won't occur until at least two to three months after the explosion, and maybe not for a year or more, if at all. But many astronomers feel that the observation of Ni^{56}, or the lack of an observation, will be as noteworthy as the neutrino observations. As Pennypacker puts it: "A lot of nucleosynthesis calculations predict its formation, but nobody's had a chance to see it."

Another theoretical prediction is that Type II supernovae form neutron stars. Astronomers hope to find one after the debris from this stellar explosion clears. It will not be easy. The neutron star will also be a pulsar and, unless its beams of radiation are pointing toward Earth, we won't be able to see it. Pennypacker has already gone south to look for a neutron star, but if success comes, it may take months or even years.

Long-term observations of 1987A will also yield valuable information. Woosley makes the point that the nearness of the LMC provides astronomers "with a unique opportunity to study a supernova with lots of instruments we could never use before." These instruments have already given us the all-important neutrino observations and will allow much more sensitive observations in the radio, infrared, x-ray, and gamma-ray parts of the spectrum (the latter two regions, which can only be seen by the Japanese ASTRO-C satellite, are where the Ni^{56} emission occurs). Astronomers will then have a complete history of this supernova in unprecedented detail, which will serve as a baseline for future supernova studies.

What will be the legacy of supernova 1987A? Craig Wheeler envisions that the intense interest generated by this supernova will cause "a tremendous wave of research in every area." From observational astronomy to theoretical physics, from stellar evolution to studies of the interstellar medium, the ripples from this wave will spread throughout the universe.

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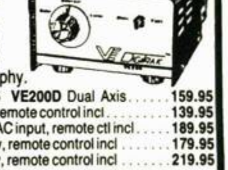

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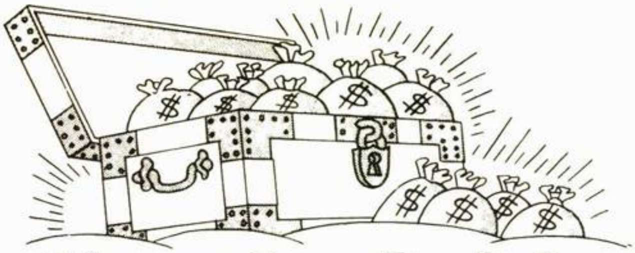

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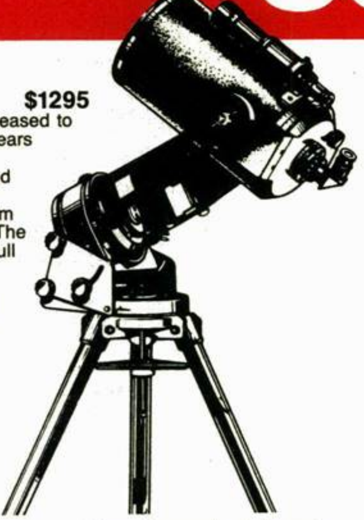

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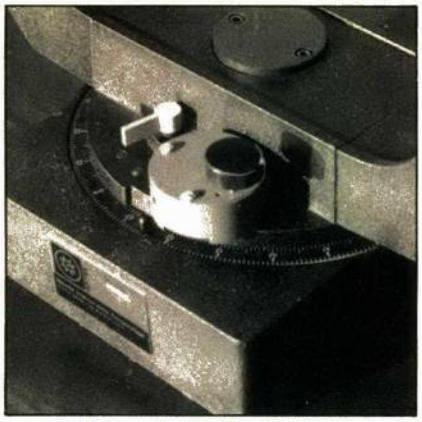

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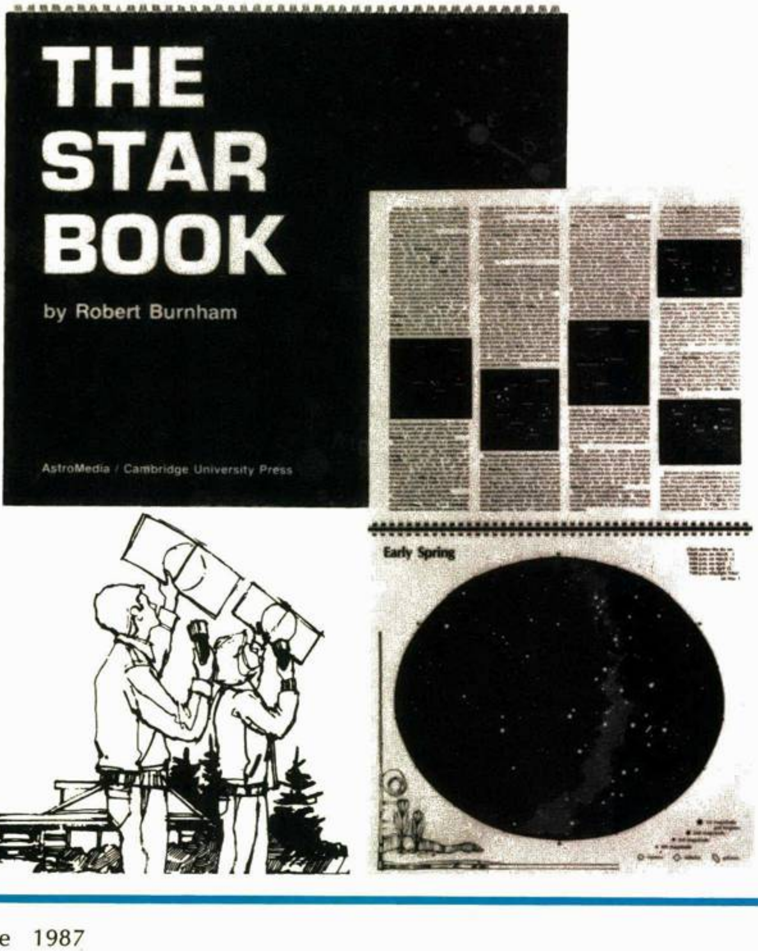

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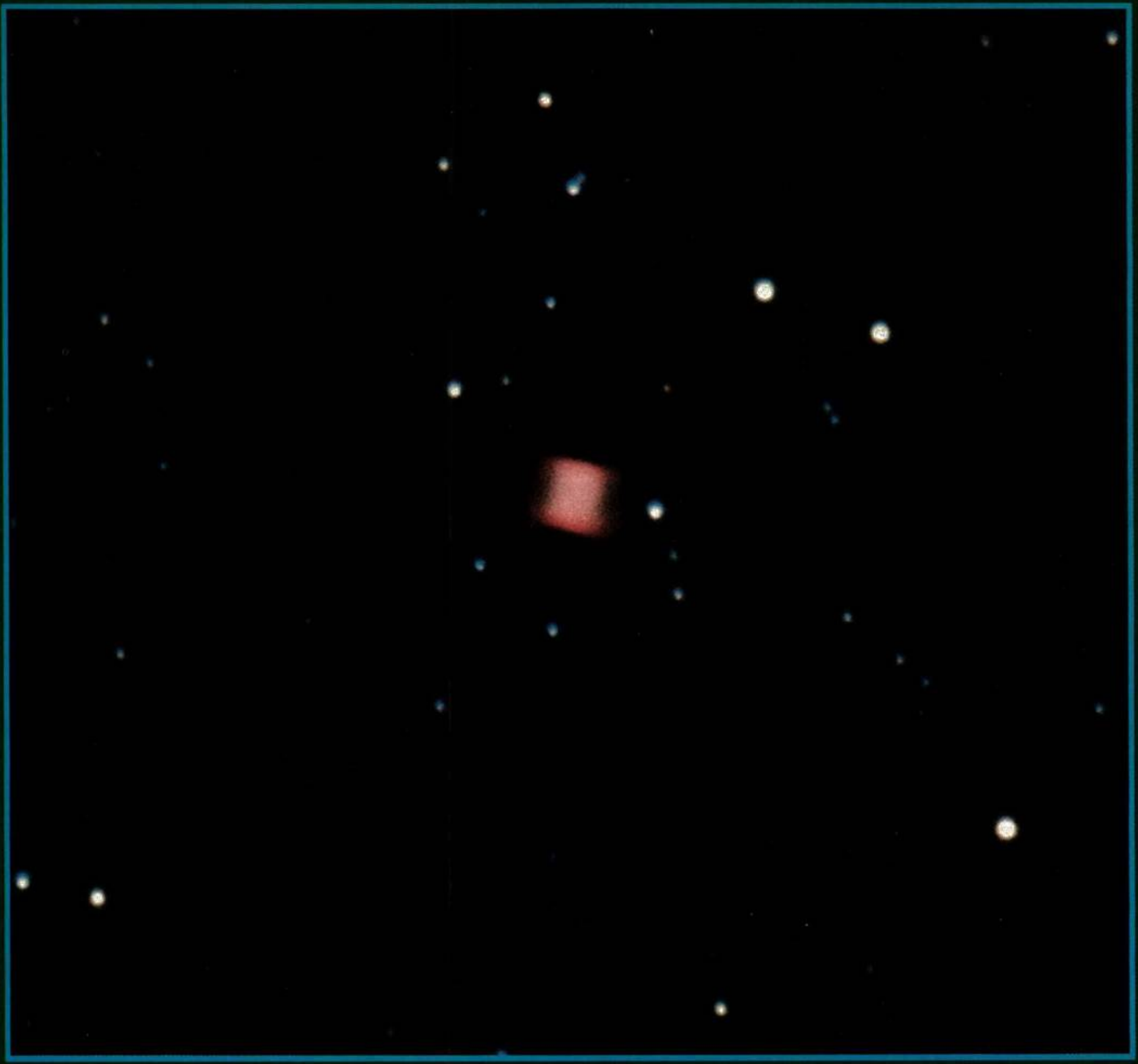


Above: The oddly shaped planetary nebula IC 4406 in Lupus shines at photographic magnitude 10.6 and covers nearly 30″. It is visible in 6-inch or larger scopes as a box-shaped smudge of light.

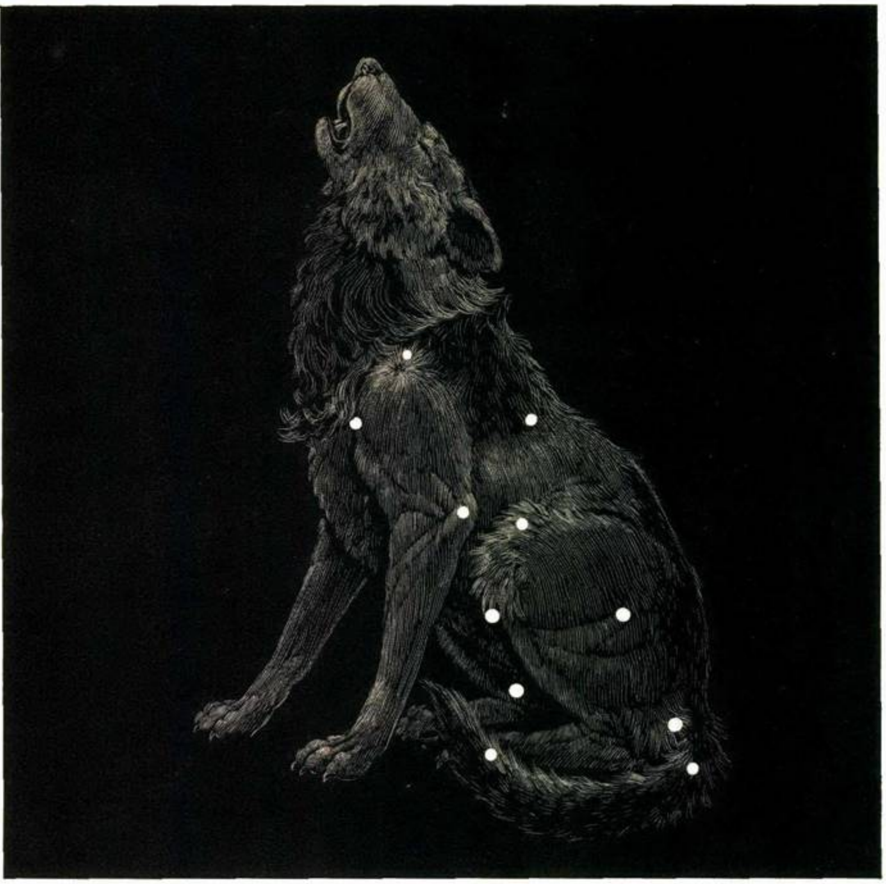
Left: Far more elegant but not as bright is the ring-shaped planetary Shapley 1 in Norma. Although it is larger than Lyra's famous Ring Nebula, Shapley 1 glows dimly at photographic magnitude 13.6 and therefore has a very low surface brightness. Photos by Jack B. Marling.

Lupus

Lup
Lupi

Norma

Nor
Normae



Keith Ward

The constellations **Lupus** the Wolf and **Norma** the Carpenter's Square lie between the bright, star-filled Milky Way star groups Centaurus and Scorpius. Although neither Lupus nor Norma contains nearly as many deep-sky objects as its larger neighbors, both constellations do offer bright examples of open and globular star clusters and several unusual planetary nebulae. Most of these objects are visible in binoculars or small telescopes when Lupus and Norma are relatively high in the sky. For many North American observers, however, this never happens.

Of Lupus' varied objects, probably the most intriguing is the oddly shaped planetary nebula **IC 4406**. This object shines at photographic magnitude 10.6 and has a long dimension of only 28'', so its average surface brightness is relatively high. IC 4406's central star, embedded in a dense cloud of nebulosity, glows dimly at photographic magnitude 14.7. It is exceedingly difficult to spot with backyard telescopes.

Locating IC 4406 is easy: start by centering your telescope's finder on the triangle of 4th- and 5th-magnitude stars formed in part by Iota (ι) and Tau (τ) Lupi. (This triangle lies 10° east and 2° north of the great globular cluster Omega [ω] Centauri.) The planetary lies about 2° north-northeast of the 5th-magnitude star that marks the triangle's apex.

Once you find IC 4406, don't be afraid to use high power to inspect its minute details. A 4-inch scope at 100x shows IC 4406 as merely a tiny, faint cloud of gray light. A 6-incher at high power, however, reveals that IC 4406 is distinctly box-shaped. A 12-inch scope shows this nebula as a bright, bluish-gray patch of light that is clearly rectilinear.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Ten degrees east and 2.5° south of IC 4406 is the planetary nebula **NGC-5882**, a far different type of object. To locate NGC-5882, position your finder scope on Mu (μ) Lupi and then move slightly over 2° north. You'll come to a field containing two bright stars, one 7th magnitude and one 8th magnitude. The planetary lies within this field, but you may have to look very carefully. Because NGC-5882 spans a mere 7'', gently sweeping the telescope from side to side will probably be required to spot the planetary with certainty. It will appear as a tiny, "out-of-focus star" that may look somewhat bluish-green. NGC-5882's photographic magnitude is 10.5, so it is bright enough to observe with small telescopes working at high power.

Another fine planetary nebula lies near the eastern border of Lupus roughly midway between the bright stars Chi (χ) and Theta (θ) Lupi. **NGC-6026** is a 45''-diameter planetary, thought to be a galaxy until 1955 when the University of Texas astronomer Gerard de Vaucouleurs identified it as a member of our Galaxy. This object lies 2° southeast of Chi Lupi and can be located easily by following an imaginary line from Chi through the 5th-magnitude double star Xi (ξ) Lupi and then extending the line for an equal distance.

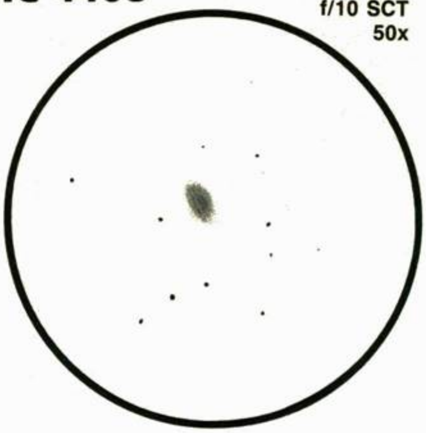
NGC-6026 is a rather large planetary nebula, and with a magnitude of 12.5 it has a very low surface brightness. A 10-inch scope shows this object as a uniformly illuminated, faint haze with a condensed, nearly stellar nucleus. Successively larger apertures show little more than an interesting field full of stars.

The remaining bright deep-sky objects in Lupus are star clusters. Northwestern Lupus holds the fine globular cluster **NGC-5824**, found less than 1° southeast of a 5th-magnitude star. Shining at 9th magnitude and measuring 6.2' across, NGC-5824 is recognizable as a cluster when viewed through just about any telescope. This cluster is strongly condensed toward its center and is therefore difficult to resolve with backyard telescopes. But on a dark, transparent night partial resolution is provided by a 12.5-inch scope at high power.

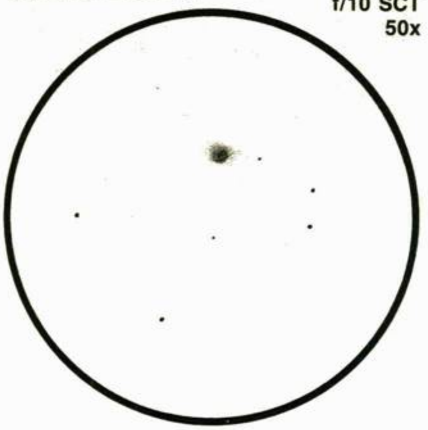
Bigger and brighter than NGC-5824 is the globular **NGC-5986**, a cluster sandwiched between the 5th-magnitude star h Lupi and a row of three 7th- and 8th-magnitude stars on the constellation's eastern side. NGC-5986 measures 9.6' across and glows at magnitude 7.1, which make it easily visible as a large, fuzzy disk of light. It is relatively simple to resolve NGC-5986 into constituent stars, and a 6-inch scope at high power shows many individual points of light ringing the cluster's edges.

Still more impressive is the globular cluster **NGC-5927**, lying in the southeast part of Lupus about 3° northeast of Zeta (ζ) Lupi. Shining at magnitude 8.3 and covering 12', NGC-5927 appears in small telescopes as a nebulous haze peppered

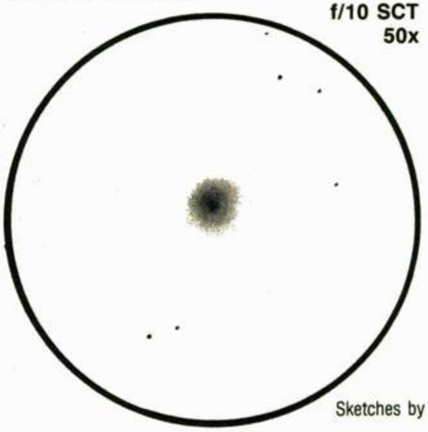
IC 4406



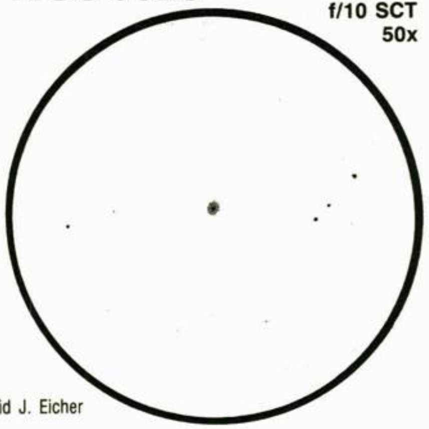
NGC-5824



NGC-5986



NGC-6026



Sketches by David J. Eicher

with tiny stellar points; its central core is bright white, unresolvable, and surrounded by a field full of sparkling stars. It is a magnificent sight.

Two bright open clusters can be found in south-central Lupus. **NGC-5749** is a 9th-magnitude group of thirty stars compressed into an area measuring only 8′ across. This cluster appears like a small clump of light in binoculars and is transformed into a respectable and captivating collection of stars in small telescopes. **NGC-5822** is a much brighter and larger group; consequently, it requires a large field of view. This cluster contains 150 stars in an area spanning 40′ and has a total photographic magnitude of 6.5. The cluster's brightest stars shine at 10th magnitude, which makes NGC-5822 visible in small telescopes as a large, scattered field of bright and faint stars loosely comprising a cluster.

As with Lupus, the most captivating object in Norma is a planetary nebula. **Shapley 1**, named for American astronomer Harlow Shapley, is one of the most elegant planetaries in the sky, a perfectly round ring of nebulosity 76″ across. Although it is as large as the famous Ring Nebula in Lyra, Shapley 1 is nowhere near as bright. With a photographic magnitude of 13.6, the light from Shapley 1 is spread out over a large enough area that it has a low surface brightness. Consequently, this planetary is difficult to spot with anything less than an 8-inch telescope under a very dark sky. If you see a faint, ring-shaped nebulosity, look for the 14th-magnitude central star from which the nebula formed.

Another planetary in Norma is the well-observed **Vorontsov-Velyaminov 78**. Named for the Russian astronomer who identified the nebula, VV 78 lies less than 1° southwest of the 5th-magnitude star Kappa (κ) Normae. Although it glows as dimly as Shapley 1, VV 78 is much smaller (27″ in diameter) and therefore has a far higher surface brightness. VV 78 appears like a bright, round, gray patch of light with no central star and is surrounded by a pretty star field.

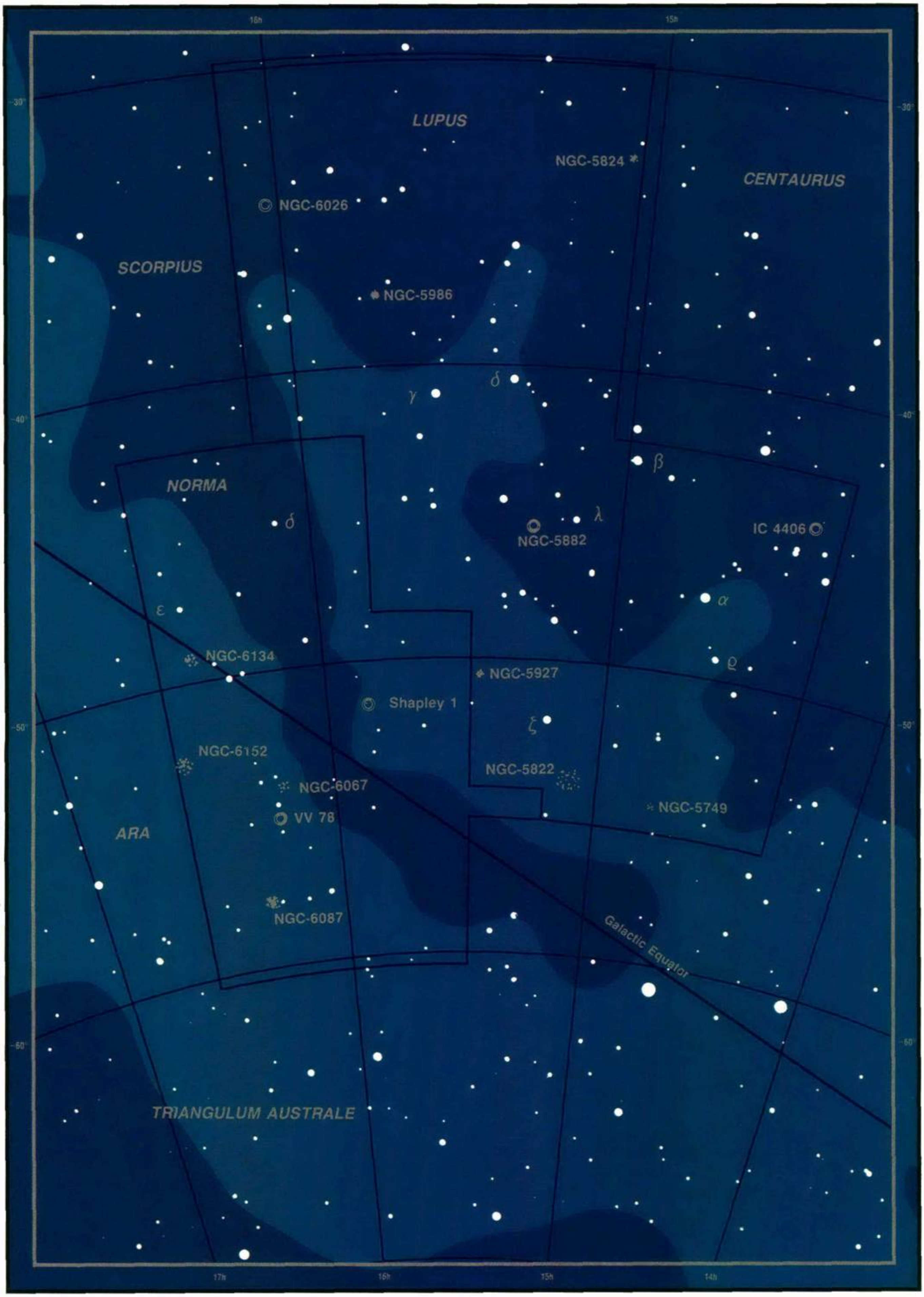
Four open star clusters are strewn across Norma, and each offers a different combination of qualities for small scope observers. About 1.5° east of VV 78 is the fine cluster **NGC-6067**, a group of one hundred stars of 8th magnitude and fainter packed into an area some 13′ across. Among the stars in this group are a number of bright pairs that form an attractive sight in nearly any size telescope. Three degrees west of NGC-6067 is the splendid star group **NGC-6087**, a cluster of forty stars of 8th magnitude and fainter in an area 12′ across. This group's total magnitude is 5.4.

Lying near the eastern edge of Norma are the bright open clusters **NGC-6134** and **NGC-6152**. NGC-6134 is a bright group of 9th-magnitude and fainter stars some 7′ across; its total magnitude is 7.2. NGC-6152 is a group of seventy stars shining at 8th magnitude and is a wonderful sight in binoculars. Its stars, 11th magnitude and fainter, cover as much sky as the Full Moon.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
IC 4406		■	14h 22.4m	−44°09′	10.6_P	28″		14.7_B
NGC-5749		⊙	14h 48.9m	−54°31′	8.8_P	8′	30	
NGC-5824		●	15h 04.0m	−33°04′	9.0	6.2′		
NGC-5822		⊙	15h 05.2m	−54°21′	6.5_P	40′	150	10_P
NGC-5882		■	15h 16.8m	−45°39′	10.5_P	7″		12.0_B
NGC-5927		●	15h 28.0m	−50°40′	8.3	12.0′		
NGC-5986		●	15h 46.1m	−37°47′	7.1	9.6′		
Shapley 1		■	15h 51.7m	−51°31′	13.6_P	76″		13.9
NGC-6026		■	16h 01.4m	−34°32′	~12.5	45″		
NGC-6067		⊙	16h 13.2m	−54°13′	5.6	13′	100	8.3
VV 78		■	16h 14.5m	−54°57′	12.6_P	27″		
NGC-6087		⊙	16h 18.9m	−57°54′	5.4	12′	40	7.9
NGC-6134		⊙	16h 27.7m	−49°09′	7.2	7′		9.3
NGC-6152		⊙	16h 32.7m	−52°37′	8.1_P	30′	70	11_P

⊙ *Open Cluster*
● *Globular Cluster*
■ *Planetary Nebula*

N★ = number of stars; Mag.★ = magnitude range of cluster or magnitude of central star


16h
15h
-30°
-30°
LUPUS
NGC-5824
CENTAURUS
NGC-6026
SCORPIUS
NGC-5986
δ
γ
-40°
-40°
β
NORMA
δ
λ
NGC-5882
IC 4406
α
ε
NGC-6134
ϱ
NGC-5927
Shapley 1
ζ
-50°
-50°
NGC-6152
NGC-5822
NGC-6067
VV 78
NGC-5749
ARA
NGC-6087
Galactic Equator
-60°
-60°
TRIANGULUM AUSTRALE
17h
16h
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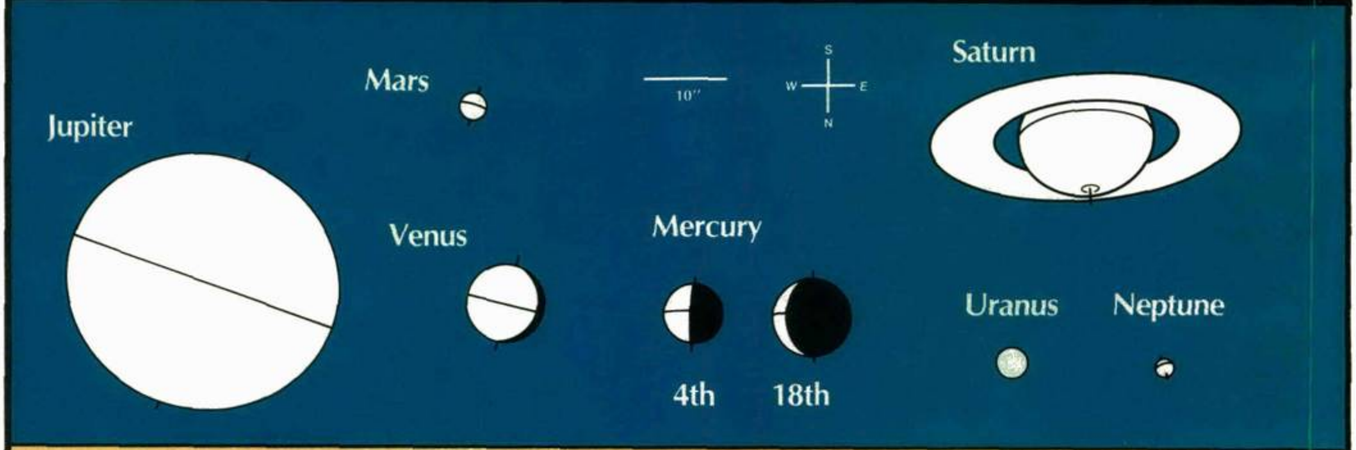
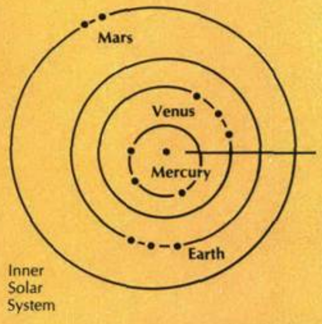
14h

Planetary Data June 1987


Mars
10″
S
W
E
N
Saturn
Jupiter
Venus
Mercury
Uranus
Neptune
4th
18th

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from:		Longitude:		R.A. (2000.0)	Dec.
						Earth	Sun	Heliocentric	Ecliptic		
Sun		1	−26.7	31.6′	—	1.014	—	—	70°00.3′	4h 34.2m	21°58.7′
		15	−26.7	31.6′	—	1.016	—	—	83°23.8′	5h 32.0m	23°17.2′
		30	−26.7	31.5′	—	1.017	—	—	97°42.6′	6h 34.3m	23°12.5′
Mercury	☿	1	0.0	7.1″	51%	0.945	0.390	181°21.1′	92°31.9′	6h 11.9m	25°31.6′
		15	−1.3	9.6″	23%	0.698	0.452	228°04.5′	105°24.6′	7h 07.5m	22°32.7′
		30	−4.3	11.9″	2%	0.564	0.464	296°52.4′	104°15.8′	7h 00.5m	18°51.2′
Venus	♀	1	−3.9	10.8″	92%	1.551	0.725	15°21.3′	46°33.7′	3h 02.8m	15°47.6′
		15	−3.9	10.4″	95%	1.607	0.724	37°43.0′	64°47.2′	4h 12.0m	20°09.0′
		30	−3.9	10.1″	97%	1.656	0.722	61°46.3′	83°04.3′	5h 29.9m	22°53.0′
Mars	♂	10	1.8	3.7″	98%	2.501	1.630	117°43.1′	103°03.0′	6h 57.2m	23°55.1′
		20	1.8	3.7″	99%	2.544	1.638	122°15.3′	109°29.3′	7h 25.1m	23°09.3′
Jupiter	♃	15	−2.2	36.6″	99%	5.382	4.953	13°09.9′	23°33.9′	1h 29.0m	8°02.3′
Saturn	♄	15	0.0	18.4″	100%	9.018	10.029	258°02.6′	257°37.1′	17h 06.8m	−21°16.0′
Uranus	⛢	15	5.5	3.9″	100%	18.198	19.213	264°42.9′	264°58.1′	17h 38.1m	−23°30.0′
Neptune	♆	15	7.9	2.3″	100%	29.247	30.235	276°32.2′	277°09.9′	18h 31.0m	−22°11.9′
Pluto	♇	15	13.7	0.1″	100%	29.800	29.686	218°54.7′	217°37.8′	14h 42.5m	1°45.4′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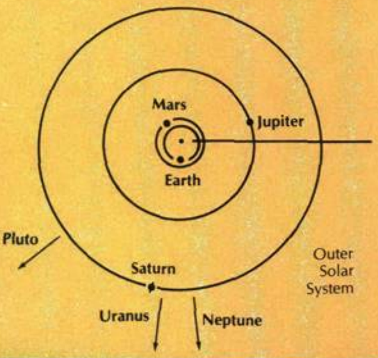
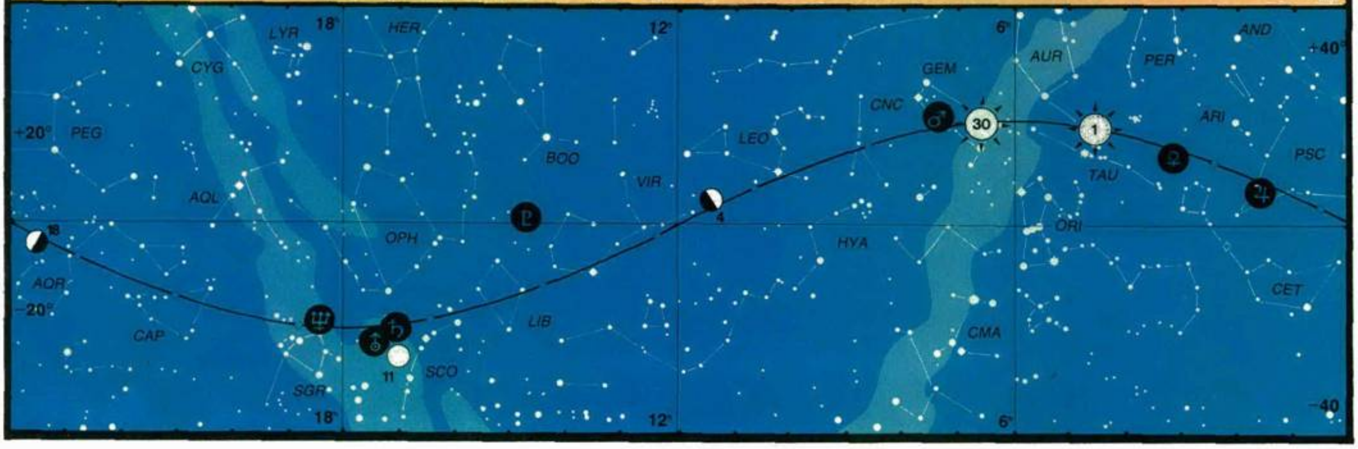

Mars
Jupiter
Earth
Pluto
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

First Quarter. . . . . .June 4 at 18h53m
Full Moon. . . . . .June 11 at 20h49m
Last Quarter. . . . . .June 18 at 11h02m
New Moon. . . . . .June 26 at 5h37m
First Quarter. . . . . .July 4 at 8h34m
Full Moon. . . . . .July 11 at 3h33m
Perigee: June 13 at 1h14m. . . . . .359,221 km
Apogee: June 28 at 4h16m. . . . . .406,429 km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AQL
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ORI
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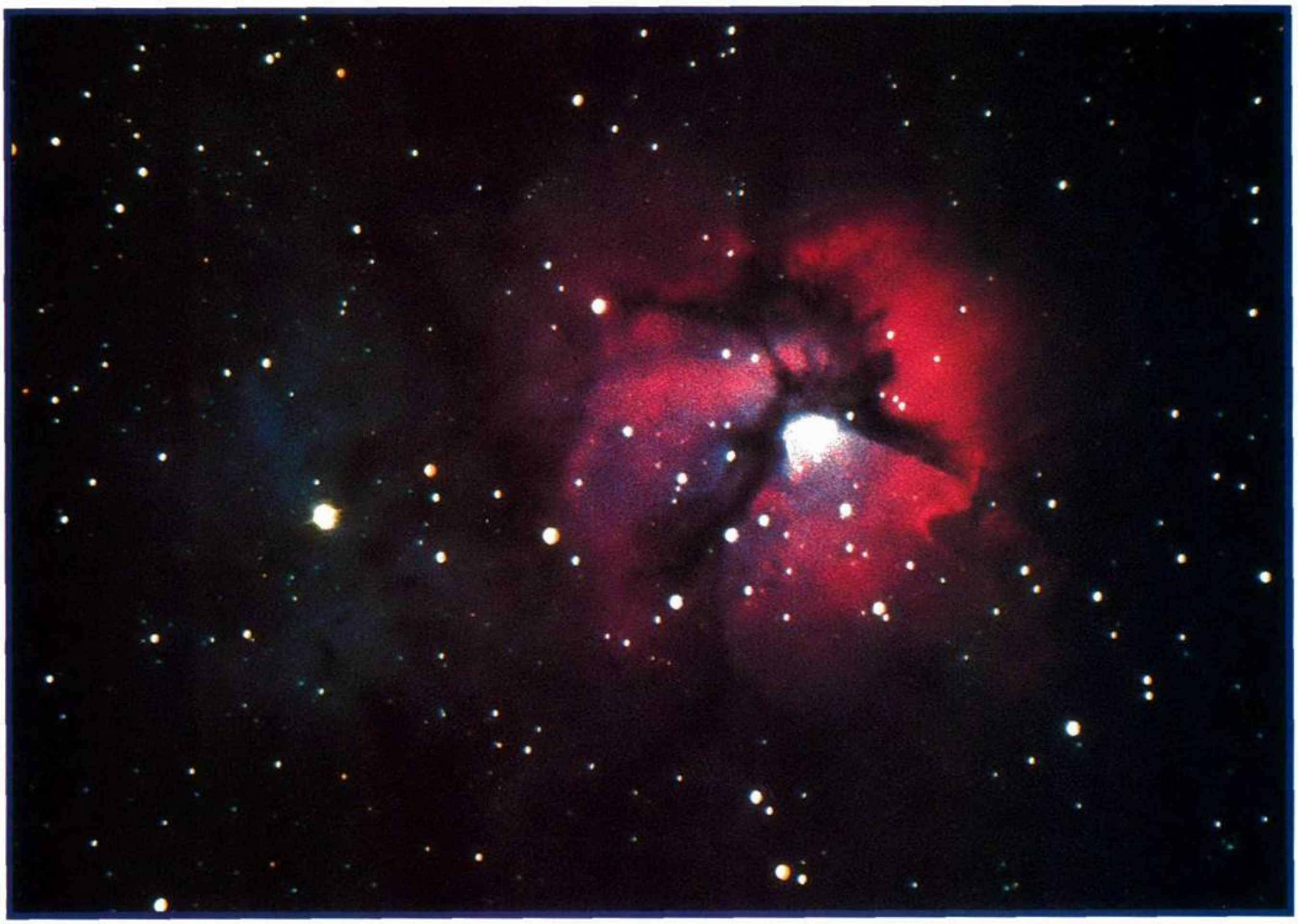
−40



One of the brightest emission nebulae in the summer sky is M-20, the Trifid Nebula in Sagittarius. Its ruddy glow is caused by hydrogen ionized by nearby hot stars; the bluish light represents dust grains softly glowing by reflected starlight. Photo by Bill Iburg, who used a 14-inch SCT at f/9, chilled Ektachrome 400 film, and a 30-minute exposure.

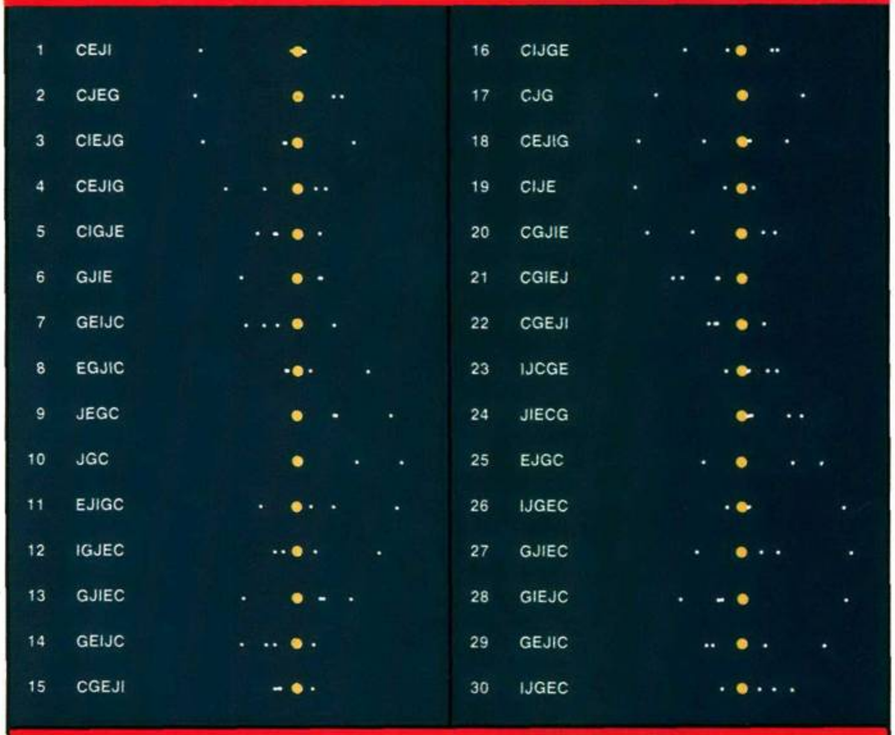
Mercury

During the first three weeks of June Mercury continues and brings to a close its fine evening apparition (one of the year's best) that began last month. Greatest elongation comes on June 7. At its most visible a few days before the 7th, Mercury will be about 11° high in the west-northwestern sky. While this isn't an enormous elevation, it is adequate for telescopic viewing if you observe from a spot with an uncluttered horizon.

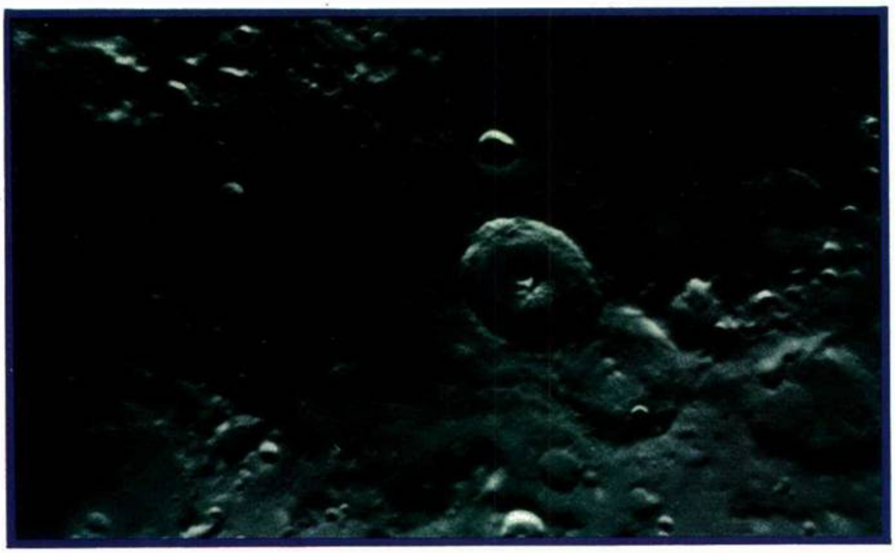
Mercury's disk will be 8″ to 9″ across; its brightness decreases steadily from 0.0 magnitude on June 1 to 2.2 by the 21st, when it will be too close to the Sun to be visible. Be sure not to miss its close approach to Mars on June 10, when the two planets will lie only 37′ apart.

This month's viewing opportunities should not be passed up. After inferior conjunction on July 4, Mercury's morning apparition in July and August will not be as good as it is this month because the planet won't attain as high an elevation.

Satellites of Jupiter — 9h00m UT



Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Left: The lunar crater Theophilus lies northwest of Mare Nectaris and is easily observable with small telescopes. Photo by L. H. Price, who used a 6-inch f/7 Newtonian at f/80, Tri-X film, and a 1/2-second exposure.

Nonetheless, the planet is visible from about July 15 until August 10; peak elevation (7°) comes on July 28, a few days past greatest elongation on the 25th.

Venus

Time is running out for seeing Venus in a dark sky. During June Venus rises shortly before the Sun and soon disappears into the bright blue of daytime. Yet once spotted, Venus can be kept in view easily as the sky lightens, provided you track it with an equatorial mounting. (Altazimuth scopes can also follow it, though somewhat awkwardly. Use a low-power eyepiece and don't let the planet drift uncentered for more than a minute or you'll be likely to lose it.)

Any telescope will show Venus as a white, featureless disk about 10″ across that looks like a tiny gibbous Moon. When seen against a dark sky, however, the disk's gibbous appearance will be masked by glare. To see the effect clearly, simply wait until dawn sufficiently reduces the contrast between disk and sky.

In July Venus' elevation will drop sharply, and the planet will finally disappear behind the Sun on August 23. Late in October it will reappear low in the western sky as it begins an evening apparition that will last until next June.

Mars

Like Venus, Mars is rapidly fading from view. After its meeting with Mercury on the 10th, it will drop toward the Sun, though more slowly than Venus does. Measuring 3.7″ across on the 15th, Mars presents little but a bright, distinctly nonstellar disk in even a large telescope. Conjunction with the Sun comes on August 25, and the planet won't reappear in the morning sky until October.

Minor Planets

1 Ceres (magnitude 6.9) is at opposition in Sagittarius on June 20. Its positions:

1st: 18h 12m 28s, −24° 36.0′
10th: 18h 04m 43s, −25° 10.0′
20th: 17h 55m 05s, −25° 45.2′
30th: 17h 45m 22s, −26° 15.8′

Ceres rises soon after sunset and is visible all night.

2 Pallas (9.0) is moving retrograde among the stars of Corona Borealis; it passes 5′ north of 4th-magnitude Gamma (γ) Coronae Borealis on the 9th and 1.3° south of 2nd-magnitude Alpha (α) Coronae Borealis on the 24th. Pallas' positions:

1st: 15h 49m 04s, 26° 29.8′
10th: 15h 42m 27s, 26° 21.2′
20th: 15h 36m 39s, 25° 43.1′
30th: 15h 32m 49s, 24° 40.4′

Pallas is only a month past opposition and remains visible the entire night.

3 Juno (9.9) is moving slowly eastward in central Aquarius. Its positions:

1st: 22h 06m 22s, −1° 29.5′
10th: 22h 12m 13s, −0° 50.1′
20th: 22h 17m 06s, −0° 16.6′
30th: 22h 20m 02s, 0° 02.9′

Juno rises around midnight on June 15.

198 Ampella (12.2) is at opposition in Ophiuchus on June 12.

1st: 17h 32m 22s, −26° 19.9′
10th: 17h 22m 10s, −25° 33.3′
20th: 17h 11m 23s, −24° 38.8′
30th: 17h 01m 27s, −23° 39.7′

Ampella rises around sunset and is viewable all night.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking them. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Though observing Jupiter requires getting up early, the planet is splendidly placed for viewing during June, July, and August. This month Jupiter lies well above the horizon haze in the southeast as dawn brightens, and by the end of August it will be in view in the east by 11 p.m. local daylight time.

Jupiter is a large, bright, and feature-filled object for telescopic viewing. It spreads 37″ across the equator (its polar diameter is 34″), and at least some cloud features are easy to see in any telescope. Jupiter rotates so rapidly that its disk visibly changes after only fifteen to twenty minutes.

The Jovian "day" lasts only 9h55m40s (or 0.413657 day), so if you observe at the same time each morning, you will see, at the disk's center, a Jovian meridian 150.3° west of the previous day's. (This rotation rate is for Jovian latitudes greater than 10° north or south.) In the planet's equatorial regions the rotation is 9h50m30s (or 0.410069 day), and the daily change is 157.9°. These rates differ by a little over 7-1/2° per day and fall into step with each other approximately every 47 days.

Experienced observers know that picking out low-contrast details on a bright object like Jupiter works best when the eye isn't dazzled by extra light. Therefore, don't stop your Jupiter watching when morning twilight begins. Instead, stay at the eyepiece and look closely for faint dark bands, irregularities, or small white spots on the disk. You'll be surprised at how more detail seems to be there in the twilight than in the "dark-sky" view.

Saturn

On June 9, Saturn reaches opposition and is visible all night. The planet is a year away from aphelion and is therefore about as small as we ever see it at an opposition.

Yet the rings are now tipped as fully open as possible. The next year or two offers your best chances for finding the elusive Encke division that lies near the outer edge of the outermost ring, the A ring. Best results will come with excellent seeing, moderate aperture telescopes, and high magnifications. Direct your attention to the ansae, the parts of the ring that lie directly east and west of the planet's disk.

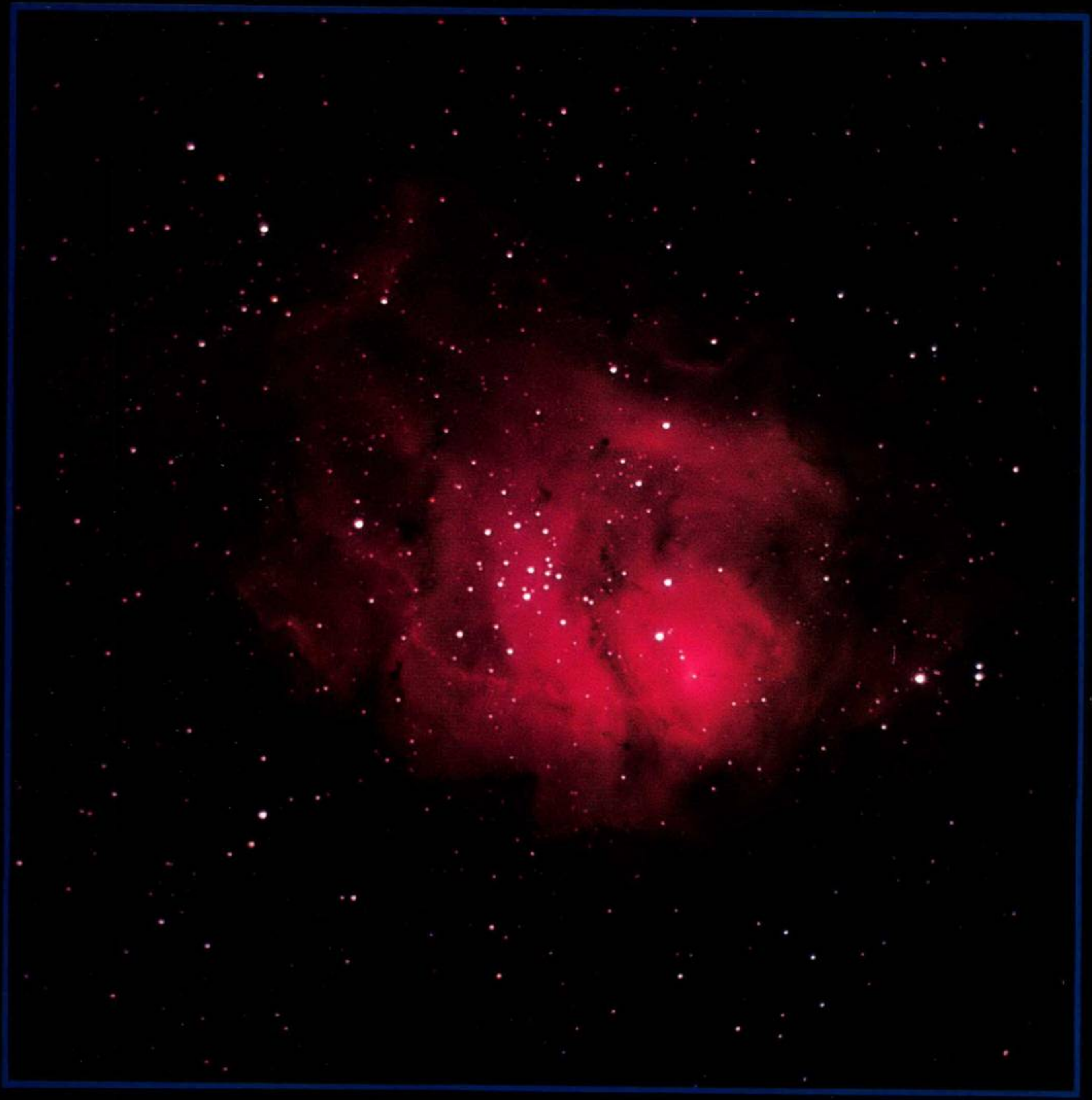
As the weeks pass after opposition, try to spot Saturn's shadow where it falls across the rings. (At opposition, of course, it lies hidden directly behind the disk.) You should start to spot it directly beside the disk on the eastern side of the rings by early July.

Uranus

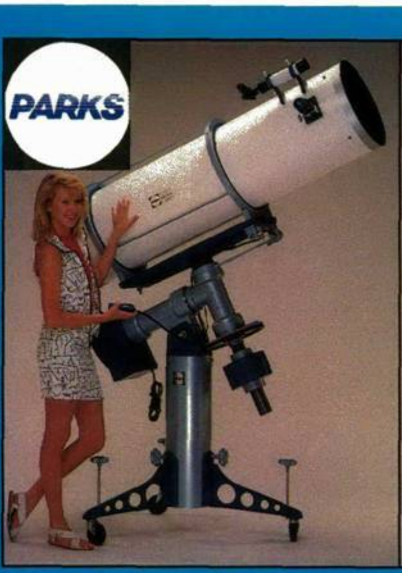
Besides Saturn, both Uranus and Neptune reach opposition this month — Uranus on the 16th. About 4° northeast of 3.3-magnitude Theta (θ) Ophiuchi, Uranus has a 6th-magnitude greenish-blue disk 3.9″ across. (A finder chart is on page 108 of the January 1987 issue.)

Neptune

Opposition for Neptune comes on June 28, when Neptune will lie about 3° north of 2.8-magnitude Lambda (λ) Sagittarii (see the finder chart on page 108 of the January 1987 issue). Neptune's grayish disk measures 2.3″ across and shines at 8th magnitude.



Dan Gordon's shot of the Lagoon Nebula in Sagittarius nets this month's $100 "Best Astrophoto" award. Gordon used an 8-inch f/6.2 SCT, hypered Fujichrome 500 film, and a 40-minute exposure.



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Elec. Clock Drive w/Slo-Motion Control ... $299

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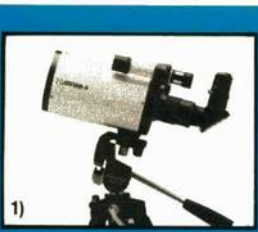
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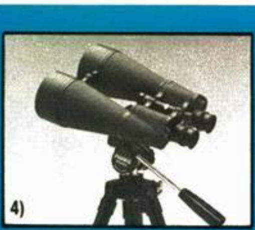
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